Date Due

GUNSHOT INJURIES

HOW THEY ARE INFLICTED
THEIR COMPLICATIONS AND TREATMENT

BY

COLONEL LOUIS A. LAGARDE

UNITED STATES ARMY MEDICAL CORPS (RETIRED)

LATE COMMANDANT AND PROFESSOR OF MILITARY SURGERY, U. S. ARMY MEDICAL SCHOOL; PROFESSOR OF MILITARY SURGERY, MEDICAL DEPARTMENT, N. Y. UNIVERSITY, ETC., ETC.

Prepared under the Direction of the Surgeon General United States Army and Published by Authority of the Secretary of War

NEW YORK
WILLIAM WOOD AND COMPANY.
MDCCCCXIV

THE · MAPLE · PRESS · YORK · PA

PREFACE

The necessity for a book on Gunshot Injuries for the use of the military services and the American surgical profession was not apparent until very recently. After the conclusion of our great Civil War the volumes of Otis[1] supplied all the wants of the profession in this particular branch of surgery. The matter in the volumes referred to was rich in variety and so well suited to the requirements of the clinician and students of surgical literature that it became the reference work of the medical profession the world over. But the subject of Gunshot Injuries as a whole has been so modified by radical changes in the armament of the nations and the results in wounds by firearms have been so modified by modern methods of treatment, that the works of Otis and his contemporaries have now been entirely superseded as far as practical surgery is concerned.

The demand of the military and civil surgeon now requires a presentation of the important subject of gunshot injuries as inflicted by a new armament, and treated after the methods of modern surgical practice. The characteristic features of the wounds by the former, and the results attained in them by the latter have entirely revolutionized military surgery, so that the wounds by firearms of fifty years ago and the results of the treatment then in vogue form no guide for a study of the subject to-day.

Some authors on military surgery have sought from the time firearms were first used to treat gunshot injuries in war, as a specialty in surgery, apart from the class of gunshot wounds the civil practitioner is called upon to treat in civil practice. A careful study of the subject will show that there has been but little difference in the character of the large majority of the wounds from these sources. Wounds observed in the two conditions mentioned have for the most part been caused by similar weapons. In the evolution of firearms the rifle of the sportsman has differed but little from the military rifle, and the same may be said of pistols and revolvers, except that in civil practice wounds were more often inflicted by bullets having less weight and caliber, possessed with lower velocity, and animated by less

[1] Medical and Surgical History of the War of the Rebellion, Parts I, II, and III, Surgical Vols., by Geo. A. Otis, Surg., U. S. A.

energy. This does not apply to the days of the code duello, because then the weapon used in personal combat was, ballistically speaking, similar to the military hand weapon of that day and the character of the wounds inflicted in military and civil practice was the same.

In our day reduced caliber rifles employing steel mantle projectiles used by armies and the sporting world alike, serve to maintain the similarity in wounds seen by the military and civil surgeon, and since the automatic hand weapons of the pistol and revolver class using steel mantle projectiles are coming into use in the civil population and the military services, the similarity of the wounds seen in peace and war will be further emphasized.

In recent wars the use of hand grenades, bombs and other devices which are made to burst by the agency of high explosives is becoming common, but the civil practitioner has opportunities to see the lacerated wounds from nitroglycerin and all of its modifications now extensively used in engineering projects everywhere so that the character of these wounds is not peculiar to the military service.

The difference in environment has probably done more than any other one thing to cause the earlier military surgeons to regard gunshot injuries in war as a special branch of surgery, and that came largely from the fact that military surgery is mostly made up of emergency surgery. But during these industrial times the practice of the civil surgeon is to a large extent made up of emergency surgery, and like his confrères in military practice he is well versed in all the resources of first-aid to the injured.

In great wars the military surgeon has exceptional opportunities to observe gunshot wounds of all kinds. Here again we find that gunshot injuries form a branch of surgery common to the military and civil surgeon because armies are never provided with sufficient relief personnel in peace to meet all the exigencies in war. As example we find that the civilian surgeons out-numbered the regular medical officers in the Spanish-American in the ratio of 1 to 6, and in the great Civil War 1 to 66. When war is declared assistance has to come from the medical gentlemen in civil life and history shows that their services are more than welcome, and that they have always responded most willingly to their country's call in times of stress.

In the following chapters the author has as far as possible presented the characteristic features of wounds by the old armament in preantiseptic times, and compared these with the results of gunshot injuries by modern arms in the Spanish-American, Anglo-Boer,

Russo-Japanese and Turko-Balkan Wars. He has also availed himself of the character of wounds by firearms in civil life and their results as compared to similar wounds in the military service. Like observations have also been made to a less extent on wounds by different kinds of rifles, pistols and revolvers on animals, experimentally and in the hunt.

There is a medico-legal aspect involved in the subject of gunshot injuries that is not treated as a rule in books on military surgery, but we know that the military surgeon is often called into courts to testify in cases having a medico-legal bearing and that it would appear to be his duty as much as that of the civil surgeon to acquaint himself with this part of the subject, hence the chapter on The Medico-legal Phases of Gunshot Wounds.

The bulk of the matter in the following chapters has been culled from lectures which for more than twelve years have formed the basis for teaching in civil and military medical schools—the method of teaching in the one has differed but little from that employed in the other.

The chapter on Field X-ray Apparatus has been confined to a discussion of types of apparatus which have been found most suitable for field work. We believe that good radiography can only be done by trained radiographers; especially is this so under the unfavorable conditions which obtain during active service and for this reason all description of radiographic technique has been omitted from this work. For the entire rendition of this chapter we are indebted to Captains Henry F. Pipes, W. A. Duncan and Arthur C. Christie, Medical Corps, U. S. Army.

The first chapter was revised in the office of the Chief of Ordnance and the part of the chapter on Ballistics was written in that office under the supervision of Colonel John T. Thompson, O. D., U. S. Army.

The remaining chapters were revised in the office of the Surgeon General by Lt. Col. F. A. Winter, M. C., U. S. A., to whom I am indebted for valuable assistance.

L. A. L.

Washington, *January* 1, 1914.

CONTENTS

CHAPTER I

Technical Considerations

CHAPTER II

Characteristic Lesions Caused by Projectiles

CHAPTER III

Symptoms of Gunshot Wounds

CHAPTER IV

Infection of Gunshot Wounds

CHAPTER V

Treatment of Gunshot Wounds

CHAPTER VI

Gunshot Wounds of the Head, Face and Neck

GUNSHOT WOUNDS

CHAPTER I

Technical Considerations

1. Definition of a Gunshot Wound; 2. Firearms; 3. Explosives; 4. Projectiles; 5. Ballistics

1. DEFINITION

The term gun has descended to us from those earlier days of the use of firearms when large guns like cannons, mortars, and the hand cannon carried by two men, were the only weapons used in war. Hand weapons like the musket, rifle, carbine, pistol and revolver were unknown until the lapse of several centuries, hence the phrase "gunshot wounds," which is now employed to designate the injuries caused by firearms. The surgical term—gunshot wound—has a wider application for the military surgeon than that usually understood by the surgeon in civil life. For the latter the term includes those wounds occurring in civil communities from missiles fired from portable firearms, viz.: weapons like shotguns, sporting rifles, pistols, revolvers, toy pistols, air-guns, etc. Such weapons propel missiles like bullets of varying caliber, lead pellets, powder grains, with and without wads, by means of a sudden explosive force resulting from the generation of large volumes of gases which are liberated by igniting explosive materials.

Under the term gunshot wounds the military surgeon includes in his battle returns all wounds resulting from the effects of any explosive force. For instance, to him the wound caused from a splinter of wood detached by a fragment of shell is as much a gunshot wound as the injury which might have resulted from the shell fragment itself. The same may be said of the wounds that result from an explosion or any explosive contrivance of whatever kind such as a bomb, terrestrial mine, torpedo, or any engine or implement used in war. In medico-military parlance any missile that is set in motion with sufficient velocity by a sudden expansive force may cause a gunshot wound.

2. FIREARMS

For a proper estimate of the nature and character of gunshot injuries as the subject appears in our literature, the surgeon should familiarize himself with the evolution of firearms, their projectiles, and the explosives which have been employed for the purpose of inflicting injuries from the earliest times. He should further have knowledge of the mechanics of projectiles as far as that part of the subject may relate to motion, velocity, and energy.

In discussing firearms proper it is only necessary for our purpose to review briefly the evolution of weapons, giving the name and the salient features of each, reserving greater space for the more important subjects of projectiles, the mechanics of projectiles, etc.

Firearms and Other Machines used in War.—Firearms of the military class are divided into those of the artillery and the so-called hand-weapons. Under the former will be included large guns, field guns, and other engines employed in war.

Large Guns.—These are breech-loading rifled guns, the largest and heaviest types being used on large war vessels and in seacoast fortifications. The longest of these guns is about 50 feet, the weight about 130 tons and the caliber about 16 inches. They fire shot and shell, made from the hardest steel, weighing about 2400 pounds, with an initial velocity of about 2250 f.s. These large projectiles penetrate steel armor 21 inches in thickness at a distance of 5000 yards. These heavy guns have various calibers down to 3 inches.

Mobile Artillery and Siege Guns.—These vary in caliber from 3 inches to 6 inches. The most common of the field guns is the 3-inch breech-loading steel rifle which accompanies an army in the field, while the heavy field or siege cannon, such as the 6-inch howitzer and 4.7-inch gun, are used principally against fortified positions. All these types employ shell and shrapnel.

Howitzers.—These are cannon of 3.8-inch, 4.7-inch and 6-inch caliber in our army, but shorter than the guns of the same calibers. They fire projectiles at lower velocities and at higher angles than guns.

Mortars.—Are also cannon shorter than the guns or howitzers and are fired at lower velocities and with higher elevations than the latter. They are principally used to throw projectiles over fortified places or intervening obstacles into fortifications or bodies of troops which cannot be reached by ordinary gunfire, or upon the decks of vessels.

Machine Guns.—This class of guns is used by all armies under

different names. In our service we now employ the Automatic Machine Rifle, cal. .30 (Benét-Mercié system), which fires the infantry rifle ammunition at great speed.

Hand Weapons.—This is a class of firearms to which the term hand-weapon has been given because they are carried by the soldier and fired from the hand or shoulder. This class includes the military rifle, the carbine, revolver and pistol.

The Military Rifle.—This weapon is now carried by all soldiers of the line except field artillery, viz.: cavalry, infantry, the marines and sailors. It represents the perfected weapon which has been evolved in the process of gun-making from the hand-cannon to the magazine breech-loading rifle. In order to properly appreciate the significance of the military rifle, the following summary of the different stages in the development of firearms will be of assistance:

Hand Cannon.—These guns originated in the East, from which they were introduced into Europe in 1446. They were the first portable firearms of which we have any record. The hand-cannon was a small cannon carried by two men and was fired from a rest on the ground and later from two-forked sticks.

Hand Gun.—The hand gun followed the hand-cannon; the barrel was longer and was made of brass fixed in a wooden stock, and like its predecessor, was fired by a lighted match applied by the hand to a touch hole at the rear end of the barrel. The projectiles were made of stone, iron, or lead, and the recoil was received by a breast plate instead of the shoulder.

Match Lock.—The hand gun was followed by the match lock, which was provided with a swinging cock holding a burning taper. The latter was gradually approached to the powder in the firing-pan around the touch hole, by pressing a trigger, underneath, with the finger. These weapons were used in war for nearly two hundred years, when guns with more complicated devices were adopted.

Wheel Lock.—This is a gun invented in Germany about 1515. The powder in the pan was ignited by sparks, which emitted from sulphurous pyrites resting against a rapidly revolving wheel set in motion by pressing the trigger.

The Snap Haunce Gun.—This gun followed the wheel lock. It derives its name from a pecking hen. In this the wheel was replaced by a cock which struck a steel-faced cover over the pan. It employed pyrites to produce the spark and it preceded the use of the more effective flint lock. The operation of firing with all the preceding

weapons was slow, about one shot per minute. The bullets were round, weighing 10 to the pound.

The Flint Lock.—This mechanism employed a flint fixed in the hammer which on striking the steel-faced cover of the pan caused sparks to ignite the powder overlying the vent or touchhole. It was first used by the French and English in about 1642 and descended to us from these nations during the earlier settlement of our country. It continued in use for nearly two hundred years, when it was replaced by the percussion cap gun. It is the gun with which we fought our first three wars. At the beginning of the last century, the size of its balls was reduced from 10 to 14 1/2 to the pound, the charge of powder was 6 drams, and the bore of the gun was .753 inch diameter.

Percussion Cap Gun.—The percussion musket has a hollow pin screwed into the vent which insures direct communication with the powder charge. A copper cap charged with fulminate powder is placed over the pin which on being struck by the hammer detonates and in turn ignites the explosive in the chamber of the gun. It was first used in the English Army in 1839 (though invented in 1807) and in our army in 1842.

The smoothbore percussion musket used in the armies at this time had calibers ranging from .63 to .75. It fired a bullet made of soft lead weighing from 315 to 400 grains and the charge of black powder was from 75 to 130 grains. The projectiles were round with initial velocities ranging from 540 to 950 feet per second and the effective range rarely exceeded 350 yards.

The imperfect fit of the ball in smoothbore barrels permitted the escape of so much of the powder gases at the time of discharge of these guns, with consequent loss of velocity and energy, that the gun makers next turned their attention to the correction of this defect, and in so doing they evolved the hand rifle, which has since become so valuable to the soldier and sportsman.

The Military Rifle.—The earlier patterns of rifled arms still employed round balls in barrels with straight grooves. The balls were a trifle larger than the bore of the gun, and they were forced down to the charge by the use of a ramrod. Later the bullets were elongated to allow more of the surface of the missile to come in contact with the barrel. The fit of the ball was so tight that it was necessary to employ a hammer in addition to the ramrod, and hammers for the purpose were added to the equipment. This secured a better fit between the ball and barrel, which in turn added to the energy and extended the

range of the ball by retaining it longer in the barrel while the explosive was generating gases in greater volume and consequently adding greater pressure. The elongated bullets fired from the first rifles were apt to tumble or lose their balance, and this was overcome in a measure by giving the straight grooves in the barrel a slight twist or spiral turn at the rate of one complete turn in 78 inches. This added stability to the bullet, keeping its point forward in flight for a greater time, and it also added to the range, energy and accuracy of fire. This principle in ballistics and the improvement of explosives have added greatly to the effectiveness of projectiles.

To overcome the extreme difficulty and the loss of time in loading with the ramrod and hammer, in 1841 Delvigne, a French army officer, conceived the idea of making a hollow in the base of the bullet next to the explosive, so that the force of the gases might press the soft lead into the metal grooves in the barrel. This prevented the escape of gas and added to the value of the rifle. Later, in 1847, Captain Minié suggested placing an iron disc in the cup at the base of the bullet. The pressure of the gases forced the iron disc forward, thereby securing more expansion of the lead. This added greatly to the effectiveness of weapons, and although Captain Minié's improvement related only to the projectile, the rifles of that day generally went by the name of Minié rifles. The iron device in the bullet, which was later changed to a boxwood plug, was employed in the Enfield rifle of the English and by other armies, whatever might be the name of their weapons.

The following were the principal features of the Minié rifle corresponding with the earlier makes of our Springfield rifle:

MINIÉ RIFLE, 1851 to 1866

Weight with bayonet	10 lb. 8 3/4 oz.
Diameter of bore	.702 inch.
Number of grooves	4
Twist	1 turn in 78 inches.
Diameter of bullet	.690 inch.
Weight of bullet	680 grains.
Charge of powder	150 grains.
Sight for 100 to 1000 yards.	

In 1855 we made still further reductions in the muzzle-loading Springfield rifle, as follows:

Caliber	.58 inch.
Weight of bullet	500 grains.
Charge of powder	60 grains.

The twist was shortened to one turn in 36 inches, and this was the gun used by our army until 1866.

Breechloaders.—The desire of tacticians to increase the rapidity of fire on the line, led to the adoption of breech-loading weapons. Although breechloaders were known since the reign of Henry VIII, they never came into practical use until the Germans used the device under the name of the Needle Gun in the Austro-Prussian War of 1866. At this time we converted the Springfield rifle of our army to a breechloader by adding a breech lock which was made to work on a hinge forward, and we reduced the caliber to .50. The device was simple; slight pressure of the thumb of the right hand opened the chamber for the reception of the metallic cartridge which had then come into use. Our troops were equipped with this gun till 1873, at which time a new model was introduced. The caliber was reduced to .45, the twist was shortened to 1 turn in 22 inches to give the elongated bullet more stability, the powder charge was retained at 70 grains, and the weight of the bullet was reduced to 405 grains. These improvements increased the velocity to 1315 f.s. with a point blank range of 350 yards and a maximum effective range of 2000 yards. We now had a weapon which in expert hands could be fired as often as twenty shots per minute. This was one of the most effective guns of its time. It compared with the German Mauser, the Lee-Speed of the English, the Lebel of the French, and the Spencer, Sharp and Maynard of the sporting world. The ingenuity of man had thus caused rapid strides in gunmaking in one generation, but those who marveled at these marked changes were scarcely prepared for the wonderful improvements that were soon to follow.

Magazine Breechloaders with Reduced Caliber.—The rapid means of locomotion in modern times have made it possible to concentrate large bodies of troops at weak points, and to ward off attacks by means of inferior numbers, so that tacticians sought greater rapidity of fire. This led to the introduction of the magazine rifle, a weapon which carries five or more cartridges in a magazine that may be placed (a) in a tube under the barrel, (b) in a tube in the stock, (c) detachable or fixed under the receiver, or (d) to one side of the receiver. Guns with fixed magazines under the receivers are preferable. Such magazines give the piece better balance and have been adopted by nearly all the great military nations. Our first magazine rifle of reduced caliber was adopted in 1892 under the name of the Krag-Jorgensen rifle, named for its inventors, two Norwegians. This weapon differed from its prede-

cessor, the Springfield breech-loading rifle, in caliber, and the adoption of the magazine which is placed below and to the right of the receiver. Its principal features were as follows:

Magazine fixed, right side	yes.
Clip	5 cartridges.
Cut-off	yes.
Safety lock	yes.
Weight without bayonet	9.19 lbs.
Length of barrel	30 inches.
Caliber, inches—mm	.30–7.62
Number of grooves	4
Depth of grooves	.004
Length of twist, turn	1 in 10 inches.
Direction of twist	to right.
Weight of cartridge	435–442 grains.
Bullet, material of envelope	cupro-nickel steel.
Bullet, material of core	lead and tin.
Bullet, length of	1.26 inches.
Bullet, diameter	.308 inch.
Bullet, weight of	220 grains.
Weight of charge	35–42 grains.
Propellent	smokeless, nitrocellulose.
Initial velocity	2000 feet per second.
Velocity of rotation of bullet, muzzle	2400 turns per second.
Muzzle energy in foot-pounds	1954.

The other features of the gun are described by Major George D. Deshon,[1] M. C., U. S. A., as follows:

"The magazine is below and to the right of the receiver. Access to it is gained by a gate, hinged below, which opens parallel to the bore. The cartridges are dropped sideways into the receiver through the open gate, either singly or in any number up to five at one time, which is the capacity of the receiver. Closing the gate presses a spring on the cartridges, forcing them successively around under the receiver and finally into it from the left side. A cartridge having thus been placed in the receiver, the bolt handle is pushed forward and then downward and to the right, the bolt pushing the cartridge forward into the chamber, and a lug on the forward end of the bolt engaging in a recess in the bottom of the receiver firmly locks the bolt and sustains it under the shock of discharge brought about by pressure on the trigger. To open the receiver the bolt handle is

[1] Association Military Surg. Journal, Vol. III, 1893.

turned upward and to the left and then pulled directly to the rear. The first part of the movement retracts the firing-pin and unlocks the bolt. A hook on the front end of the extractor, which lies along the bolt, next catches the flange of the empty shell and draws it back until it meets a lever in the floor of the receiver by which it is thrown out to the ground. A cut-off is provided on the left of the receiver whereby the cartridges in the magazine may be at any time shut off and held in reserve at the will of the soldier. The special advantages of this gun are the ease and simplicity of its bolt action and the facility with which it can be at any time loaded, either singly or as a repeater. It makes no difference whether the magazine is empty or partly full, whether the bolt is forward or back, whether the cut-off is open or closed, the gun can still be loaded with ease and always in the same manner, thus fulfilling every need of the hardened veteran or the impressionable recruit."

This gun corresponds in effectiveness for war to the guns of other nations that were adopted at about this time. In 1903 a new arm was perfected, somewhat similar in its magazine and bolt to the German Mauser Rifle. This is known as the United States Rifle, cal. .30, model of 1903. The weight of this, the present service rifle, is about 9 1/2 pounds; length of barrel, 24.006 inches. In 1906 radical changes were made in the ammunition, as follows: The weight of the bullet was reduced from 220 to 150 grains. Instead of an ogival head the present bullet is pointed, offering less resistance to the air. Its length has been reduced from 1.26 inches to 1.08 inches. The powder charge has been increased from about 38 grains to about 48 grains. The muzzle velocity of the new bullet has been increased from 2000 f.s. to 2700 f.s., and the velocity of rotation at the muzzle from 2400 turns to 3240 turns per second. The striking energy has been increased from 1954 to 2400 foot-pounds. The extreme range has been increased from 4066 to 4891 yards. Twenty-three aimed shots have been fired in one minute with this rifle used as a single loader and forty shots in the same time from the hip without aim using magazine fire. The ball penetrates 28.25 inches of thoroughly seasoned oak across the grain at 50 feet, Fig. 1. In the modern rifle[1] the ratio of weight of bullet to weight of gun is much less. Though the velocity of the bullet has increased very much, the velocity of recoil is less, and the soldier is able to withstand much longer the shock of recoil on the shoulder with less fatigue. Increased

[1] Ordnance and Gunnery, Lissak, op. cit.

muzzle velocity has added to the range and accuracy of fire. The trajectory is flatter and the danger space has been increased for all ranges. These advantages have been attained with a shorter barrel, which diminishes the weight of the gun and facilitates handling by the soldier. Using the battle sight, the point blank danger space is as follows:

Firing standing	203 yards.
Firing kneeling	636.6 yards.
Firing lying down	587.2 yards.

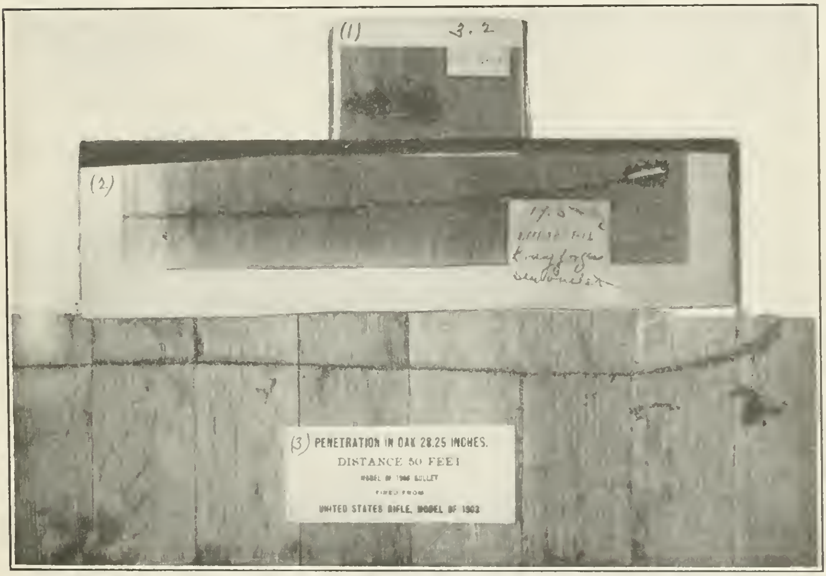


FIG. 1.—The relative penetration of U. S. Army rifle bullets in well-seasoned oak across the grain at 50 feet. 1, Penetration of .45 cal. Springfield rifle bullet, weight 500 grains, 3.2 inches; 2, penetration of .30 cal. Krag-Jorgensen rifle bullet, weight 220 grains, 19.5 inches; 3, penetration of .30 cal. new Springfield rifle bullet, weight 150 grains, 28.25 inches.

The gun is sighted for 2850 yards. In many respects this is one of the most effective guns now used by any army. The center of gravity of the bullet is placed well back, giving it but little stability on striking structures offering the slightest kind of resistance—a question which will be discussed in a later chapter.

Carbine.—This is a firearm carried by cavalry. It is very much like the military rifle, using the same or lighter ammunition, but with shorter barrel. In the evolution of the military rifle nearly all mounted troops have hitherto been provided with a carbine, since it is more easily carried on horseback. In the recent change in our service to the U. S. magazine

rifle, we have so shortened the barrel of the latter that it is easily carried by mounted troopers and the present weapon answers the purpose of both branches of the service—cavalry and infantry.

Shotgun.—This gun is so familiar to everyone that it requires no particular description. The more important subject of missiles and powder charge will be described later.

Revolvers and Pistols.—The familiar examples of revolvers in this country are the Smith and Wesson and the Colt new service double-action revolver. The United States Army was formerly provided with a .45 caliber Colt revolver, and later the caliber was reduced to .38 inch. The latter is a double-action weapon,[1] that is, it can be fired in either of two ways, by separately cocking the hammer and pulling the trigger or by accomplishing both operations with a steady pull on the trigger. When rapidity of action is required, the double-action mechanism is employed, but the fire is not so accurate. After using this weapon a number of years its stopping power was not considered sufficient. The United States Government, after many trials of the various automatic pistols, viz., the Savage, Luger, and Colt, of calibers varying between .32 and .45, recently adopted the .45 caliber Colt automatic pistol.

The Colt Automatic Pistol.—In this weapon there is a movable barrel and slide, the recoil of which ejects the empty shell, cocks the firing mechanism. and loads a new cartridge into the barrel. After the first shot is fired it is only necessary to pull the trigger for each succeeding shot as long as a cartridge remains in the magazine. The magazine of the .45 caliber pistol holds seven cartridges, while that of the .32 and .38 calibers holds eight cartridges. The magazine is enclosed in the hollow handle, is inserted from below, and is held in place by a spring and catch.[1] The bullet, composed of a lead core encased in a jacket of cupro-nickel, weighs 230 grains. The charge is about 5 grains smokeless powder, and the initial velocity about 900 f.s. The automatic pistol is superior to the revolver as a service arm for the following reasons:

1. Greater accuracy.
2. Less recoil.
3. Rapidity of fire.
4. Greater number of shots.
5. Rapidity of loading.

[1] Ordnance and Gunnery, by Lissak, op. cit.

Reloading is done in an instant by inserting an extra magazine. The moral effect of having this reserve ammunition under complete control will be of great value.

Toy Pistol.—This is really a revolver of about .22 calibers, employing generally a blank cartridge composed of a brass shell and a charge of about 6 grains of black powder, held in place by a cardboard wad. It is used in this country by boys generally to celebrate the anniversary of our National Independence. Accidents from this weapon have figured extensively in medical literature under the head of toy pistol tetanus or 4th of July tetanus, to which we will refer later.

The Flobert and other target rifles, used in shooting galleries, are generally .22 to .38 calibers in diameter. They shoot round or elongated bullets with velocity and energy sufficient to penetrate any part of the body, including the skull and brain.

3. EXPLOSIVES

The marked advances in the effectiveness of present-day firearms are largely due to the use of modern explosives, which have almost entirely superseded the use of black gunpowder as a propellent. The latter still has some valuable uses, and among explosives it is generally the first to be described.

Gunpowder is an explosive substance formed by a mechanical mixture of

Saltpeter	75 per cent.
Charcoal	15 per cent.
Sulphur	10 per cent.
	100 per cent.

Gunpowder explodes when heated to 572° F. In guns it is exploded by striking the primer in the base of the cartridge which is charged with fulminate powder. Its value as a propellent is due to the large amount of gas which it liberates on exploding. The chemical results of this explosion are: 43 per cent. of gaseous products composed of carbonic acid, and nitrogen with some carbonic oxide and aqueous vapor. The remainder of the charge is associated with the gases in the form of finely-divided solid substances. The volume of the gases at zero centigrade and under atmospheric pressure, liberated by the explosion, occupies 280 times the bulk of the charge. The pressure exerted in a closed vessel is said to be as much as 5850 atmospheres

when the charge is exploded in a space completely filled by it (Noble & Abel). The temperature of the products of explosion reaches from 2000° to 4000° C. In the explosion which takes place, charcoal furnishes the carbon and niter furnishes the oxygen to burn the charcoal and sulphur. In addition, the latter adds to the rapidity of the explosion.

Modern Explosives.—These have many uses, but to the surgeon they are of special interest when employed in war and by evil doers in attempts to destroy human life. The following are the ones more often resorted to for the purposes mentioned.

Fulminate Powder.—Although there are other fulminate powders, the fulminate of mercury is the only one used for military purposes. It is used as a detonator in exploding guncotton and other explosives, and also in charging percussion caps. It explodes instantaneously and with great force by friction and by percussion. When wet it may be handled with impunity, and when dry it burns quietly when kindled in the open air. It explodes when heated to a temperature of 360° F. The gases of the explosion are CO_2, N and vapor of mercury. Its distinguishing characters are the large volume of gas generated for the bulk of the substance used, and the rapidity and violence of the explosion. The theoretical pressure developed by the explosion of this body is 28,000 atmospheres. The explosive characteristics of the substance were displayed in the Orsini attempt to assassinate the French Emperor in 1858, when three bombs were exploded, each containing 4 ounces of mercuric fulminate: 511 wounds were inflicted on 156 persons.

Smokeless Powders.—The name of these explosives comes from the fact that they emit very little smoke on exploding as compared to black gunpowder. Two classes of smokeless powders are now or have been recently in use in our service: Nitroglycerin powder, used for the hand weapons, and nitrocellulose powder, now used for both small arms and cannon. They are both made from guncotton, but the nitroglycerin powder has from 10 per cent to 30 per cent of nitroglycerin. The temperature of the explosion of the latter material is higher, and as the erosion of the metal of the bore increases with the temperature, the life of the large costly guns is very much shortened by the use of the nitroglycerin powder. For this reason nitrocellulose powder is generally preferred for use in cannon. Another objection to the use of nitroglycerin powder for large guns, was its greater liability of spontaneous ignition when deteriorating in unfavorable storage conditions. In the hand weapons, the nitroglycerin powder is

hermetically sealed in the cartridge, and its keeping qualities and stability are preserved, and for these reasons it can be used with safety in small arms.

One of the typical nitroglycerin powders used abroad is composed of—

Insoluble nitrocellulose	67.25 per cent.
Nitroglycerin	30.00 per cent.
Metallic salts	2.75 per cent.
	100.00 per cent.

Forty pounds of acetone is the solvent for a hundred pounds of this mixture. The jelly-like paste, after various treatments in shaping and drying, is cut into bead-like grains, perforated and graphited.

Cordite.—This is an English nitroglycerin powder, composed as follows:

Nitroglycerin	30 per cent.
Guncotton	65 per cent.
Vaseline	5 per cent.
	100 per cent.

The vaseline is added to render the powder waterproof and to improve its keeping qualities.

Nitrocellulose Powder.—This is the powder used in cannon. It is composed of guncotton containing 12.65 per cent nitrogen dissolved in two parts of ether to one of alcohol. The powder issues from the press as a colloid, and it is cut into grains of suitable size and prepared as stated under nitroglycerin powder, except that cannon powder is not graphited as a rule. In our service the powder is formed into cylindrical grains with seven longitudinal perforations giving a uniform thickness of web. The powder is brown in appearance and the grain differs in size with the caliber of the gun.

In other services cannon powders are made into grains of various shapes, such as cubes, solid and tubular rods, circular cross-section, flat strips, and rolled sheets.

The advantages of smokeless powder lie in the fact that, unlike black powder, the smokeless powder is almost entirely converted into gas; and with smaller charges it is possible to give equal or higher velocity to the projectile; it leaves no residue in the bore. The theoretical pressures when exploded in its own volume, exerted by guncotton, is 24,000, and as much as 25,000 atmospheres by nitroglycerin—

more than four times greater than that developed by the explosion of gunpowder.

There are other explosives of interest to the surgeon. They are the so-called picric acid compounds, known under the familiar names of melenite, emmensite, liddite, etc. They emit fumes on exploding which irritate the conjunctiva and air passages.

The Sprengel explosives, known under the names of bellite, hellofite, and roburite, are high explosives which are harmless when the component parts are kept separated; when mixed they detonate with great violence.

Compressed Atmospheric Air.—Compressed air is used as a propellent in air guns in shooting galleries principally. Compressed air has no application as an explosive in military practice because of the limited range which it confers on the projectile.

4. PROJECTILES

The term projectile is applied to missiles from firearms in general. The term as used in these pages is synonymous with the term bullet when it refers to projectiles from hand weapons. Missiles propelled by the bursting charge of grenades, bombs, and mines are also referred to as projectiles.

Projectiles may be divided into three classes:

1. Projectiles from hand weapons.
2. Projectiles from artillery.
3. Projectiles from grenades, bombs, and mines.

Projectiles from Hand Weapons.—The hand weapons include rifles, pistols, and revolvers, shotguns, and air guns. The present-day projectiles from hand weapons, pistols, and revolvers are conveniently classed as follows: (a) penetrating bullets, (b) setting-up bullets, (c) disintegrating bullets, (d) explosive bullets.

(a) *Penetrating Bullet.*—This is a bullet made up of a core of hard lead enclosed in a mantle of cupro-nickel steel. It is the bullet of the reduced caliber military rifle the world over, and it is also employed in the automatic pistols that are now coming into such favor. This bullet rarely disintegrates in the human body, and it seldom deforms. When making a regular impact it generally penetrates point on.

(b) *Setting-up Bullet.*—This bullet is made of soft lead in order to promote deformation on impact against bony structures. This was the bullet of olden times before the days of rifle weapons and until the lead was hardened with antimony.

(c) *Disintegrating or Dum-dum Bullets.*—These bullets are also called metal patch bullets in the trade. They are mantled projectiles except at the tip end, where the lead core is fully exposed. Such a bullet readily disintegrates on impact against resistant structures like bone. The core and the steel case break up into many fragments, each acting as a projectile.

(d) *Explosive Bullets.*—These projectiles are hollow lead bullets in which an explosive is placed. A cap is fixed in the nose of the bullet to promote explosion on impact. The effects of such a bullet do not differ from those of a dum-dum projectile. Their use is proscribed by the comity of nations.

In addition to the foregoing projectiles, armies generally have blank ammunition in which the bullet is replaced by a wad of cardboard, or paper. This blank ammunition is used for ceremonies and drills.

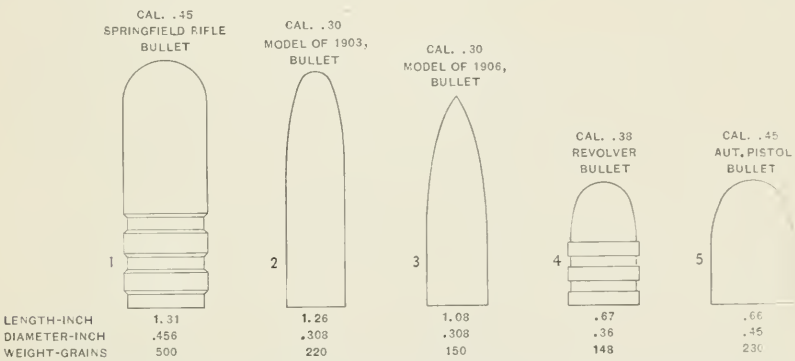


Fig. 2.—3 and 5 represent the shape and size of the rifle and pistol bullets in present use by the United States Army. 1, 2 and 4 represent the rifle and revolver bullets recently discarded.

Projectiles from Pistols and Revolvers.—These correspond very nearly in caliber and composition to the projectiles of the military rifle. They usually weigh less and they are shorter. For special reference to their shape and composition see Fig. 2, also table No. 3, pages 70 and 71.

Shotgun projectiles vary from fine lead pellets, 2020 to the troy ounce, to buckshot, which are .31 inch in diameter. The smallest pellets weigh a fraction of a grain and the buckshot weigh 38 grains. Shotgun projectiles are all round, and they are composed of hard lead. The number of missiles to each cartridge depends on the bore of the gun and the size of the pellets.

The projectile from the toy pistol is the entire charge, which is made up of the cardboard wad and about 6 grains of black powder.

The projectile from the air gun and Flobert rifle is an elongated or a .22 BB round shot made of lead hardened with antimony.

Projectiles from Artillery.—These are classed as shot, shell, and case shot.

Solid shot is no longer used in modern cannons. The projectile called a shot is now hollow with thick walls. It is principally used to perforate armor and carries a small bursting charge.

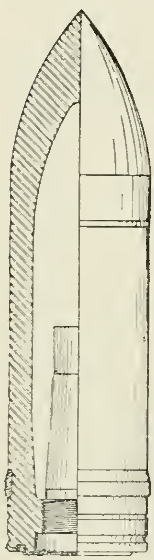


Fig. 3.—The 3-inch common steel shell used in U. S. Army.

Shell.—The shell is a hollow projectile with thinner walls than the preceding. It is also provided with a large bursting charge. It is used to destroy persons or material (Figs. 3 and 4).

Pom-pom shell is another kind of shell. It derives its name from the report of its discharge. It is fired from the one-pounder Vickers-Maxim automatic gun. It is 1.457 inches in diameter, 3 3/4 inches in length, and weighs 16 ounces. It explodes by percussion. This shell is used to kill and wound the enemy, hence like the cannon shell it breaks into many fragments.

Case Shot.—This consists of a number of shot held together in a metal case, which may be ruptured by the shock of discharge, or by a bursting charge. The term canister or grape shot is applied to the former and the term shrapnel is applied to the latter. The modern projectiles of the artillery arm are all cylindrical with an ogival head, except the canister, which has a flat head.

Canister.—In this projectile the metallic envelope is filled with small balls which are liberated by the shock of discharge. Canisters are used at short range when the guns of a battery are in danger of capture. Each 3-inch canister contains 244 iron balls, 5/8 of an inch in diameter, weighing 30 to the pound, placed in a receptacle the shape of an elongated can. The canister has been entirely superseded by the modern shrapnel.

The Shrapnel.—The shrapnel is of special interest to surgeons because of its increasing importance in augmenting the casualty list of battles in modern wars. The shrapnel is a projectile which carries a number of bullets at a distance from the gun where they are dis-

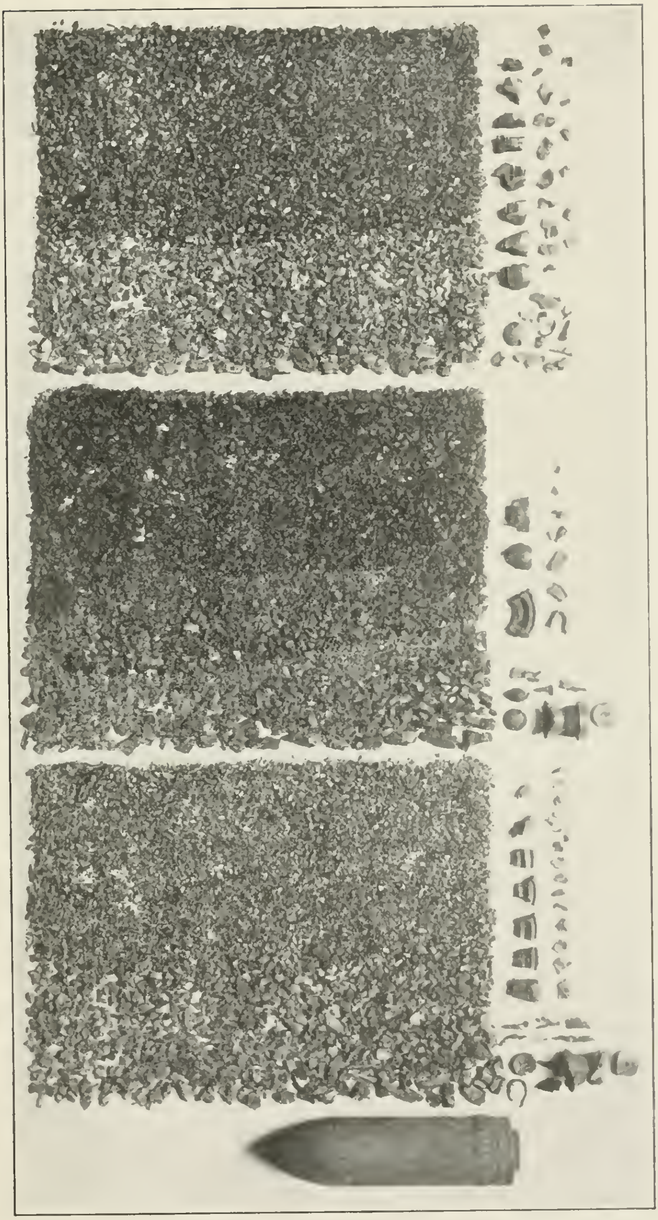


Fig. 4.—Fragmentation of 3-inch (15 pounder) shells filled with high explosive.

charged with added energy over a wide area from the point of bursting. It has become the principal projectile of all modern field artillery. It forms 80 per cent of the ammunition supply of the field guns.[1] It is used against troops in masses and material as well. It is used, also, in mountain and siege artillery, and in the smaller guns of sea coast fortifications to repel land attacks. (See Fig. 5.) In this shrapnel the case is a steel tube with a solid base. The weight of the 3-inch field-gun shrapnel complete is 15 pounds, length 10 inches, muzzle velocity 1700 f.s. The bursting charge is composed of 2 3/4 ounces black powder placed in a chamber at the base. There is a stopper of guncotton in the central tube to hold the powder in place and to assist in the explosion. There are 252 round balls, flattened on six faces, of .50 inch caliber, composed of lead hardened with antimony. The balls are surrounded by a smoke-producing matrix, which is used to locate the point of bursting. This shrapnel is said to be a man-killer at 6500 yards. At the latter distance the shrapnel has a remaining velocity of 565 f.s. On bursting, an additional velocity of 300 f.s. is conferred on the lead bullets, making altogether a remaining velocity of 865 f.s. at 6500 yards. The fuse can be set to cause the projectile to explode at any one-fifth of a second in its flight.

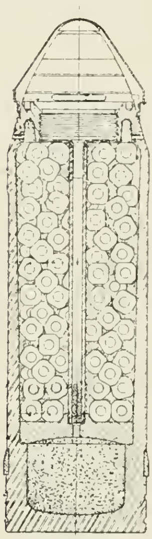


Fig. 5.—Common shrapnel used in U. S. Army.

The older shrapnels were made up of a cast-iron case and diaphragm that separated the balls. The case was constructed to invite rupture into a number of fragments. The bursting charge was placed generally in the head of the projectile. This old-time shrapnel broke into a greater number of fragments, but they were not always possessed with sufficient energy to inflict severe injury. The present shrapnel has the bursting charge located in its base. It is made of a stout case, which remains intact at the time of bursting, except for the blowing out of the head.

The following table gives the area of dispersion and other important data on shell and shrapnel used in guns of different calibers.

[1] Ordnance and Gunnery, by Ormond M. Lissak, Lt. Col., Ordnance Department, U. S. A.

AREA OF DISPERSION

		Shrapnel		Shell		
		Length, yards	Width, yards	Length, yards	Width, yards	
At a range less than 3000 yards.	Field gun	400	150	300	100	Area of dispersion about 100 yards wide and 150 yards long, very effective within a central zone of about 30 yards wide and 20 yards long.
	Mountain howitzer	300	100	250	75	
At a range over 3000 yards.	Field gun	300	125	250	75	
	Mountain howitzer	200	75	150	75	

FIELD ARTILLERY

Gun	Extreme range, yards	Shrapnel			Shell	
		Weight	No. of bullets	Size and weight of bullets	Weight	Approximate No. of effective fragments
3-inch field gun and mountain howitzer.	Gun 6500 Howitzer 5600	15 lb.	252	.5 in. 167 grains	15 lb.	600
3.8-inch gun and howitzer.	Gun 7300 Howitzer 6200	30 lb.	340	.54 in. 230 grains	30 lb.	800
4.7-inch gun and howitzer	Gun 8000 Howitzer 6640	60 lb.	711	.54 in. 230 grains	60 lb.	1000
6-inch howitzer	6704	120 lb.	1074	.6 in. 306.4 grains	120 lb.	1500

Grenades, Bombs, Mines, and Torpedoes.—Hand and rifle grenades have recently come into prominence as projectiles. Hand grenades were among the earliest forms of explosive projectiles used in war. Trained soldiers, called grenadiers, threw grenades by hand in repelling attacks, etc. The earlier grenades were composed of a hollow ball or cylinder of metal, glass or paper, 2 or 3 inches in diameter, filled

with an explosive which was exploded by a fuse upon falling among the enemy. Their employment was abandoned in the latter part of the seventeenth century. Dynamite grenades were first used at the siege of Mafeking by the besieged. The modern grenade came into special prominence in the Russo-Japanese war as a result, no doubt, of the great advances in the application of high explosives. The hand grenade of the Japanese is suspended from the cartridge belt, Fig. 6. It consists of two parts, the body and the handle. The body is a tin cylinder, 4 1/2

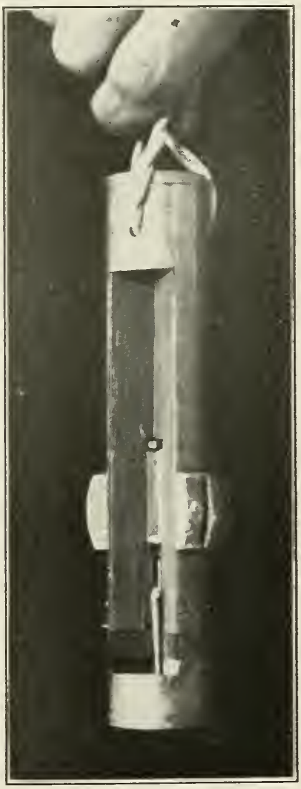


Fig. 6.—Dummy of a Japanese hand grenade.

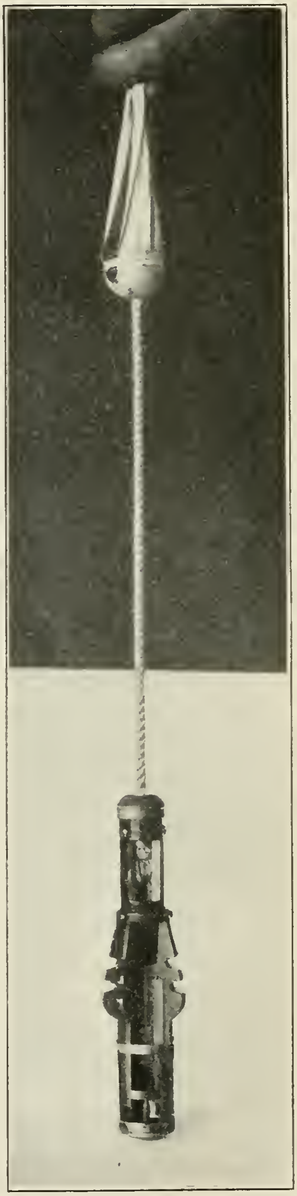


Fig. 7.

cm. in diameter by 6 cm. in length, filled with shimose powder and provided with a time fuse. The cylinder is also provided with a percussion cap at the far end. To ensure the grenade falling cap-end

Fig. 8.

first, it is piloted by a kite-tail arrangement placed at the rear end of the handle, and a weighted lead ring is fixed on the base at the opposite end of the grenade, which is provided with the cap. The grenade

Fig. 9.

breaks into many fragments, and in addition it emits a gas which causes painful irritation to the conjunctiva and air passages.

"In the latter part of the war at Port Arthur the Japanese abandoned the hand grenade for a can filled with a high explosive which was placed

in a small mortar. Some of the latter were made of wood, in which a small charge of powder gently lifted the can, which was usually filled with shimose, from 200 to 400 yards, where a frightful explosion would occur" (Lynch).

In our service we employ a grenade (Fig. 7) which corresponds very nearly to the Japanese hand grenade, except that the body is made of steel instead of tin. There is also a grenade fired from the rifle, as shown in Fig. 8. This is a great advantage, as the body of the soldier need not be exposed in propelling the grenade, as in the case of the hand grenade of the Japanese army. Fig. 9 shows the fragmentation of the U. S. grenade.

Hand Bombs.—These projectiles were extensively used by both combatants in the Russo-Japanese war at Port Arthur. The bomb of the Japanese weighed about 14 pounds. It was composed of pyroxylin and melenite placed in linen bags provided with a fuse of fulminate of mercury. The bags were suspended from the soldier's neck, and they were thrown among the enemy at opportune moments. The Russians employed a hand bomb, composed of 600 to 1400 grams of different kinds of explosives loaded into the copper case of their empty 3-inch shells, provided with a fuse. The destructive effects of such projectiles are similar to those of guncotton, viz., the violent displacement of air as detonation takes place.

Mines and Torpedoes.—Mines and torpedoes figure extensively in naval combat and in harbor defenses. The land forces are specially interested in terrestrial mines which, like submarine mines, torpedoes, etc., are made by confining a charge of explosive in a case which is exploded by clock-work, by contact, or by an electric spark under the control of an individual at a central point. The terrestrial mines of the combatants in the Russo-Japanese War were composed of wooden or metallic cases holding about 12 pounds of pyroxylin. The cases were buried 3 feet underground about 200 yards from the line of defense, disposed in two rows 40 to 50 yards apart, the mines in each row being disposed at intervals of 10 to 12 yards. The projectiles set in motion with each explosion were made up of dirt, gravel, pieces of the casing, and the rapidly displaced air at or near the locality of the explosion.

Projectiles from Gatling and automatic machine guns are the same as used in the hand rifle of foot troops described under the term penetrating bullets in the beginning of this chapter, and which will be referred to extensively in succeeding chapters.

5. BALLISTICS

I. **Motions of Projectiles.**
   (A) The motion of translation.
      1. The force of explosion.
      2. Air resistance.
      3. The force of gravity.
      4. Combined effect of forces.
   (B) The motion of rotation.

II. **The Trajectory.**
   (a) The danger space.
   (b) Factors that affect the trajectory.
   (c) Sectional density and form.

1. THE MOTIONS OF PROJECTILES

Projectiles of early form fired from smoothbore guns, being spherical, had but one motion imparted to them, that of translation. To oblong projectiles, in addition to the motion of translation, is given a motion of rotation to steady them in their flight. Attention will be given first only to the motion of translation.

(A) **The Motion of Translation.**—A projectile fired from a gun is acted upon by three forces: the force of discharge, or of explosion, which sets the projectile in motion; the air resistance, which opposes the motion of the projectile and which is therefore a retarding force; and the force of gravity, which tends to deflect the projectile toward the center of the earth. Brief consideration will be given to these forces, the effect of each separately on the projectile, and the resultant of their combined effects.

(1) *The Force of Explosion.*—The force of discharge is due to the explosion of the powder with which the gun is charged. This explosion is a chemical action between the constituent elements, which liberates gas and generates heat. A certain amount of powder will, when subjected to this chemical action, liberate a certain volume of gas, generate a certain amount of heat, and sometimes form a certain amount of solid matter or residue. Modern smokeless powder leaves practically no residue. The gas, being at a high temperature and confined to a small space, will exert a high pressure on the walls of the gun and upon the base of the projectile. The walls and the breech of a gun are designed to withstand the powder pressure, so that the expansive force of the powder gas can be expended only in driving the projectile from the gun. The projectile, therefore, leaves the bore of the gun with a

certain muzzle velocity, and for similar guns, similar projectiles, and equal powder charges, this velocity will be the same.

Slightly beyond the muzzle of the gun the powder gases cease to act on the projectile, and it moves forward with a certain velocity, which according to the laws of physics, would remain constant if there were no air resistance, or retardation due to any other medium, and no force of gravity; the projectile would then continue to travel indefinitely into space at a constant velocity.

(2) *Air Resistance.*—The effect of air resistance on the velocity of a projectile has been the subject of diligent research. From the time of Benjamin Robins and his experiments with the ballistic pendulum and the whirling machine, in the year 1742, to the experiments of Bashforth and Mayevski, in the latter part of the nineteenth century, with modern projectiles at high velocities, and to our own test and proof firings at the ordnance establishments, the science of exterior ballistics has been developed and improved to such a degree that the path of a projectile can be calculated with remarkable accuracy. From these experiments expressions have been deduced for the retardation due to the air in terms of constants depending upon the form of the projectile, of constants depending upon the velocity of the projectile, of factors of the velocity, and of factors depending upon the atmospheric condition. The retardation of the sharp-pointed bullet used in the United States rifle, caliber .30, model of 1903, or the rate at which its velocity is decreased, is calculated to be about 2100 feet per second while the bullet has a velocity of from 2600 to 2700 feet per second, about 850 feet per second while it has a velocity of from 1370 to 1800 feet per second, and about 18 feet per second while it has a velocity below 790 feet per second. These figures show that at the higher velocities air resistance is a factor of great importance.

It is seen, then, that a large portion of a projectile's energy is expended in overcoming the air resistance, that the resistance is greatest during the period at which it maintains a high velocity, and that were there no force of gravity to draw the projectile to earth the projectile would travel in a straight line but with a variably decreasing velocity until finally it came to rest at an infinite distance from the gun.

(3) *The Force of Gravity.*—Gravity is the force that attracts all bodies toward the center of the earth. It is a continuous force, and therefore an accelerating force. That is, if it acts on a free body one second it will give that body a certain acceleration, and should it cease to act after the first second the body would continue to fall at a constant

velocity, neglecting air resistance; but the force continues to act through the second second and every following second, giving the body the same acceleration each second. The acceleration due to gravity is 32.16 feet per second; this value varying slightly with the latitude and longitude of the place. *In vacuo*, then, a body falling would have a velocity of 32.16 feet per second at the end of the first second, a velocity of 64.32 feet per second at the end of the second second, of 96.48 feet per second at the end of the third second, and so on, or the velocity v at any time would be equal to gt, the product of the acceleration and time.

The height h through which a body would fall at a constant velocity equals the product of time and velocity vt. But a falling

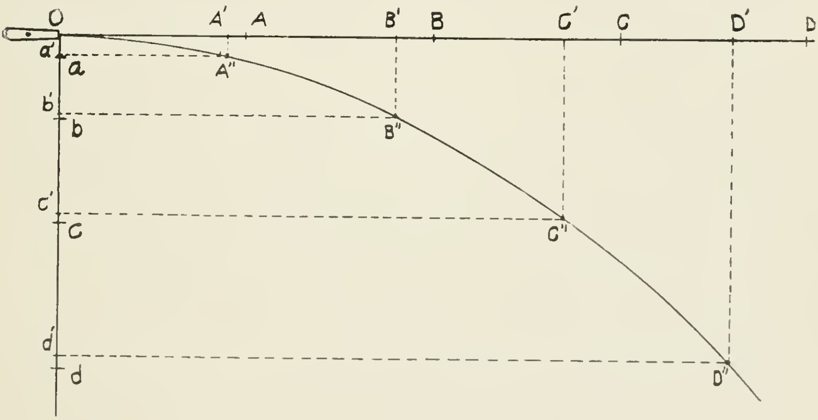


Fig. 10.

body has a variable velocity, and it becomes necessary to find an average velocity. For a body starting from rest and falling at a constant acceleration, the average velocity is one-half its final velocity. Since we have seen that the final velocity is equal to gt, the height of fall, h, equals $1/2\ gt^2$, one-half the product of the acceleration and the square of the time. Projectiles, therefore, are given an acceleration downward the instant they leave the muzzle of the gun. If the axis of a gun fired is horizontal, the projectile will have fallen 16.08 feet below this axis at the end of the first second, 64.32 feet at the end of the second second, and 144.72 feet at the end of the third second, and so on.

(4) *The Combined Effect of the Forces.*—Referring to Fig. 10, A, B, C, and D mark the distances a fired projectile will have traveled from

gun O at the end of the first, second, third, and fourth seconds, respectively, neglecting air resistance and gravity. Under that assumption we have seen that the projectile would travel in a straight line at a constant velocity; therefore the intervals between these points are equal. But, due to air resistance, the velocity of the projectile is being constantly decreased, so that actually the projectile travels only to A' during the first second and only reaches points B', C', and D' at the end of the second, third, and fourth seconds.

If, on the other hand, the projectile were dropped from the muzzle of the gun (Fig. 10), it would fall the distance Oa during the first second, to b during the second second, and to c and d during the third and fourth seconds, neglecting air resistance. But due to air resistance, it falls only to the points a', b', c', and d' during those four seconds.

Combining these two motions, the vertical and horizontal, to obtain the actual resulting motion (Fig. 10), we find that at the end of the first second the projectile will have traveled the horizontal distance OA', but it will also have fallen the vertical distance Oa', so that actually it will have reached the point A''. And similarly at the end of the following seconds, it will have reached the points B'', C'', and D'', and so on. Since the air resistance tends to bring the projectile to rest, and gravity constantly increases its velocity of fall, it is easily seen that, given the space, the projectile would tend to assume a vertical direction of motion.

(B) **The Motion of Rotation.**—To keep the oblong projectile in its direction of travel, it is given a motion of rotation about its longer

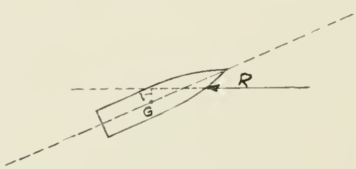


Fig. 11.

axis. This rotary motion prevents the projectile from tipping when the resultant air resistance becomes oblique to the axis of the projectile. Fig. 11 shows a projectile fired horizontally. It has a tendency to keep its axis parallel to the axis of the gun, and so long as the projectile travels in a line with its axis, the resultant air resistance coincides with its axis. But the projectile takes a course downward; so that the resultant air resistance will make an angle with the axis and passing over its center of gravity will tend to tip the projectile.

This rotation is caused by spiral grooves, called rifling, cut in the bore of the gun. As the projectile passes through the bore it engages with these grooves and is turned by them. The velocity of rotation of a projectile depends upon its linear velocity and upon the twist of the rifling. In the present .30 caliber service rifle the twist is one turn in 10 inches.

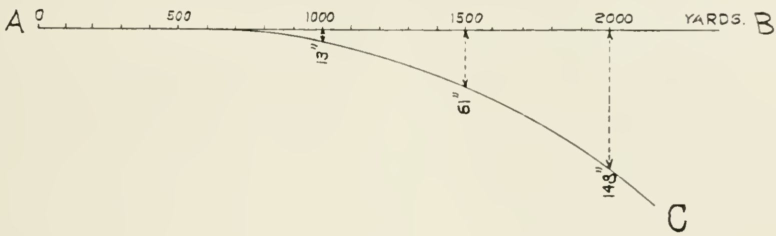


Fig. 12.

But though the rotation prevents the projectile from tipping, it causes it to deviate from the vertical plane of fire. This deviation is called drift. There seems to be a difference of opinion as to the cause of drift, whether it is a gyratory effect, or whether the projectile tends

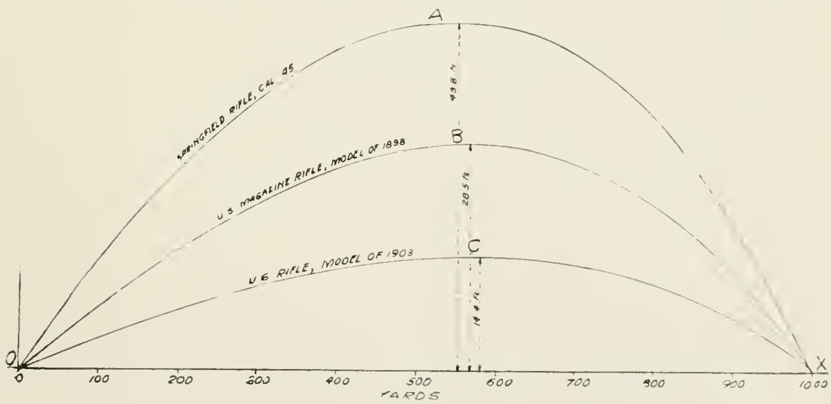


Fig. 13.

to roll on the more dense air beneath it; suffice it to know that it is due to air resistance. The drift of a gun is in the direction of its rifling, a right-handed twist causing a drift to the right, and *vice versa*.

Figure 12 shows the drift curve, up to 2000 yards, of the present caliber .30 service rifle. AC is the path of deviation of the projectile from the vertical plane AB.

II. THE TRAJECTORY

The curve described by the center of gravity of a projectile during its passage through the air is called the trajectory. *In vacuo* a trajectory would be a parabola, but the curve is greatly deformed from that of a parabola by the air resistance. Fig. 13 shows the trajectories of the caliber .45 Springfield rifle, the Krag-Jorgensen rifle, and the present caliber .30 service rifle at a range of 1000 yards.

(a) **The Danger Space.**—Fig. 14 shows the 1000-yard trajectory of the service rifle. The line *DE* is drawn horizontally a distance of 8

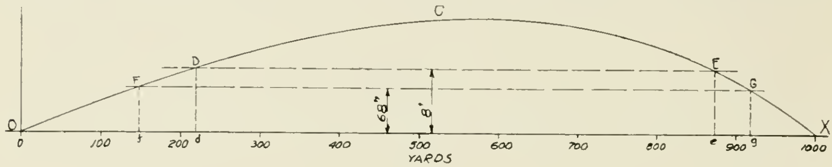


Fig. 14.

feet above the ground line *OX*, representing the height of a cavalryman, the line *FG* is drawn similarly 68 inches above the ground to represent the height of an infantryman. The points *f*, *d*, *e*, and *g* are projections of the intersections of these horizontal lines with the trajectory. It will be seen that a man on horseback will be in danger in the fields *Od*

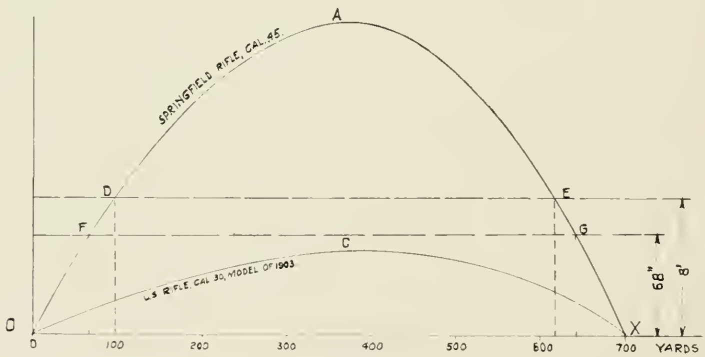


Fig. 15.

and *eX*, while a man standing will be in danger in the fields *Of* and *gX*. The danger space is the territory in which objects are liable to be hit.

Fig. 15 shows the cavalry and infantry danger spaces for the 700-yard trajectories of the caliber .45 Springfield rifle and the service rifle. The danger space of the former is quite short, while that of the latter is continuous. The flatter the trajectory the greater will be the danger space at the long ranges, as shown in Fig. 13, and the greater will be the continuous danger space, as shown in Fig. 15.

In order to increase the effectiveness of rifle fire, the construction should be such as to give the flattest possible trajectories. Fig. 13 shows the development in that direction in this country.

(b) **Factors that Affect the Trajectory.**—The curvature of a trajectory is primarily due to gravity. It is obvious that if two guns are fired horizontally, their projectiles traveling at such velocities that the first will reach a 1000-yard target in one second, the other the same target in two seconds, the former will, at the target, have fallen 16.08 feet below the horizontal plane through the muzzle of the gun, while the latter will have fallen 64.32 feet. The projectile traveling fastest will have the flatter trajectory. In order to obtain a flat trajectory, therefore, it is necessary to have a high muzzle velocity and a low air resistance.

The muzzle velocity of a projectile depends mainly upon the charge, the pressure, and the weight of the projectile, and is limited by the allowable energy of recoil and the attainable strength of the gun. The weight of a rifle must not be excessive, its recoil must not be too great, and the bullet must not be too light, lest it have insufficient stopping power.

(c) **Sectional Density and Form.**—While it is important to improve the interior ballistics of a gun in order to obtain a high muzzle velocity, it is equally important to reduce the air resistance. The formula $R = A_n \frac{\delta}{\delta_1}, \frac{c}{w/d^2} V^n$ is an expression for the retardation in feet per second due to the resistance of the air. A_n is a constant depending upon the velocity of the projectile, obtained from a ballistical table; V is the velocity of the projectile in feet per second and n is a number dependent on the velocity considered, $\frac{\delta}{\delta_1}$ is an atmospheric correction obtained from a table and is the ratio of standard density of atmosphere to the density of atmosphere at time of firing; and "c" is a form coefficient determined by experiment. The term w/d^2 is the sectional density of a projectile, and is its weight in pounds divided by the square of its diameter in inches. From the formula it will be seen that the greater the sectional density the less will be the retardation.

In order, then, to improve the trajectory by reducing the air resistance, it is necessary to increase the weight of the projectile and to decrease its diameter. A projectile's weight, however, is dependent upon the muzzle velocity desired and the recoil of the gun permitted, so that the sectional density can be improved mainly by decreasing the diameter. The diameter, on the other hand, it must be remembered,

affects the destructive capacity of the projectile and in small arms projectiles the shock effect.

The air resistance can be further reduced by improving the projectile's form. Fig. 16 shows the relative resistance of spherical-headed and ogival-headed projectiles. The resistance to the ogival head struck with a radius of two diameters is taken as unity. The resistance to a spherical head is a fourth greater, while that to the ogival head of 7 diameters radius is only about half as much. In addition to pointing projectiles, experiments are under way with rifle bullets to determine the effectiveness of a rear ogive with a view to still further reduce the retardation due to the air. In the formula above the effect of a projectile's form on the retardation is expressed in the term "*c*," which is determined experimentally.

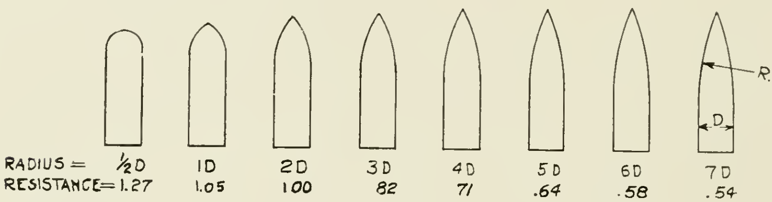


FIG. 16.

THE UNITED STATES OR NEW SPRINGFIELD RIFLE

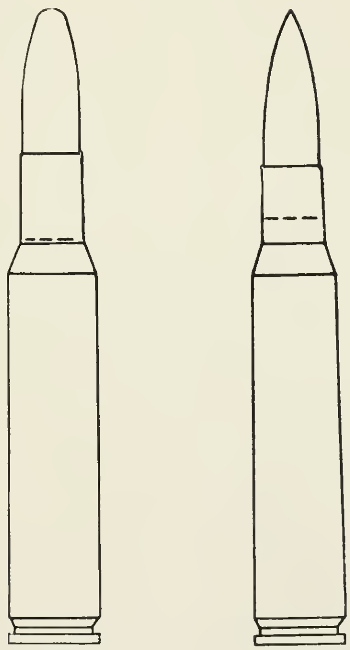
The present service rifle was adopted in 1903 on the recommendation of a board of officers, after exhaustive tests. The important changes that have been made in the rifle since its adoption are given below. The rear sight on the rifle as adopted was replaced by an improved sight in 1905. Experiences in the Russo-Japanese War showed that it was essential for an infantryman to have a serviceable bayonet, and as a result the rod bayonet was displaced in 1905 by a long knife bayonet. In 1906 a sharp-pointed bullet was adopted and a pyrocellulose powder substituted for the nitroglycerin powder. These changes resulted in an increased range, a flatter trajectory, and a longer accuracy life due to decreased erosion. To accommodate these changes a slight alteration was made in the chamber of the rifle.

UNITED STATES RIFLE, MODEL OF 1903

Weight without bayonet........................	8.69 pounds.
Weight with bayonet...........................	9.69 pounds.
Capacity of Magazine..........................	5 cartridges.
Rifling, uniform twist, one turn in 10 inches, right hand.	
Sighted from 100 to 2850 yards.	
Diameter of bore..............................	.30 inch.

BULLET, MODEL OF 1906

Length	1.095 inches.
Maximum diameter	.3085 inch.
Weight	150 grains ± 1 grain.
Material of core	96.7 per cent. of lead and 3.3 per cent. tin, approximately.
Jacket	Cupro-nickel, 85 per cent. copper and 15 per cent. nickel.
Charge, pyrocellulose powder, determined for each lot of powder, ordinarily about	48 grains.
Muzzle velocity of bullet	2700 feet per second.



U. S. Model of 1903 Cartridge. U. S. Model of 1906 Cartridge.

FIG. 17.

Fig. 17 shows the difference between the model of 1903 and model of 1906 cartridges. All U. S. Army rifles have now been chambered for the latter cartridge.

The rifle has a right-hand twist, and the drift is therefore to the right. Due to a slight lateral jump to the left, the trajectory is found to be very slightly to the left of the central or uncorrected line of sight

up to a range of 500 yards, and beyond that range it is to the right of this line. The drift at 1000 yards is 13 inches to the right, and at 2000 yards about 12 feet. The drift slot on the rear sight leaf is so cut as to partially correct for the drift.

Recent successes in the Pan-American, Olympic and Palma competitions demonstrate that we have the most accurate rifle in the world. With a high muzzle velocity and a flat trajectory, little remains to be desired in the present rifle unless the trajectory can be further lowered and the continuous danger space for a height of 68 inches extended from the present range of 730 yards to a range of 1000 yards.

The automatic rifle will, no doubt, be the military weapon of the future. All nations have experimented with rifles of this type, but so far as is known no nation has succeeded in finding an automatic rifle sufficiently reliable and effective in the hands of troops to justify the expense of adopting it in place of the rifles now in use. In 1909 the Mexican Government ordered 4000 Mondragon automatic rifles. This gun uses the same cartridge as the Mauser rifle with which the Mexican troops are armed.

The following table shows the different features of the reduced caliber rifles now in use by the armies of the world.

ND QUALITIES

von

	Powder		Bullet					Cartridge		Initial velocity m.
	Form	Weight of charge g	Shape	Coating	Core	Length mm.	Weight g.	Weight g.	Number of rounds per man	
n	Flakes	2.65	Ogival	Nickel-plated steel sheet	Hard lead	30.7	13.7	26.8	120	630
n	Disks	2.75	Ogival	Steel sheet (Oiled)	Hard lead	31.8	15.8	28.68	140	620
n	Flakes	2.5	Ogival	Nickel-plated steel sheet	Hard lead	30.2	14.1	28.0	120	600
n	Flakes	2.7	Ogival	Nickel-plated steel sheet	Hard lead	31.8	15.8	28.75	120	620
n	Flakes	2.20	Ogival	Cupro-nickel	Hard lead	30.25	14.5	30.0	120	610
n	Flakes	2.75 or 2.90	Ogival, somewhat, flattened; or pointed	Nickel or without	Hard lead or copper	30.30 or 39.2	15.0 or 13.0	29.40 or 27.60	120 120	610 or 700
n	Flakes	2.63 3.20	Ogival Pointed	Steel sheet coated with copper	Hard lead Soft lead	31.25 28.0	14.7 10.0	27.88 23.75	120 150	620 860
in	Threads	2.08	Round	Cupro-nickel	Hard lead	31.85	13.82	27.40	115	610
in	Threads	2.06	Round	Cupro-nickel	Hard lead	32.10	13.86	27.48	100	605
n	Disks	2.43	Ogival	Steel coated with cupro-nickel	Hard lead	31.44	10.33	22.1	?	720
in	Tubes	2.25	Ogival somewhat flattened	Cupro-nickel (Oiled)	Hard lead	30.2	10.50	22.0	162	700
n	Flakes	2.14	Slender Ogival	Cupro-nickel	Hard lead	32.60	10.50	22.41	135 †	710
n	Flakes	2.00	Ogival	Cupro-nickel	Hard lead	32.2	10.52	21.8	120-150	690-700
n	Flakes	2.45	Ogival	Nickel-plated steel sheet	Hard lead	30.92	10.2	22.61	160	720
in	Flakes	2.30	Ogival	Nickel-plated steel sheet	Hard lead	32.15	10.10	23.55	150	700
n	Flakes	2.91	Ogival	Steel coated with Cupro-nickel	Hard lead	32.0	10.10	24.10	?	720
n	Flakes	2.31	Ogival	Steel coated with Cupro-nickel	Hard lead	31.36	10.33	22.72	130	710
n	Flakes	2.48	Ogival	Cupro-nickel (Oiled)	Hard lead	30.2	13.75	25.80	120 †	620
	Flakes	2.54 From 2.45 to 2.65	Ogival	Cupro-nickel	Hard lead	30.30 From 30.25 to 30.86	11.20	From 24.60 to 24.96	From 120 to 150	Between 690 and 700
n	Flakes	2.36	Ogival	Cupro-nickel	Hard lead	32.12	10.12	23.55	120	710
n	Vermicelli	2.0	Ogival	Steel coating, with paper-wrapping (oiled)	Hard lead	31.7	13.9	27.5	150	600
n	Flakes	2.65	Ogival	Nickel-plated steel sheet	Hard lead	30.7	13.7	26.8	120 †	630

TABLE 1.

RIFLES NOW IN USE: BRIEF COMPARISON OF DATA ON THEIR CONSTRUCTION, MATERIAL, AND QUALITIES

(Translated by V.J. from the "Tabelle 2" appended to "Die Entwicklung der Handfeuerwaffen——von G. Wrzodek——Leipzig——1908")

Caliber mm.	Country	Model	Year of Introduction	Length without bayonet m.	Length with bayonet m.	Weight without bayonet kg.	Rifling number of grooves and direction of the twist	Length of the twist mm.	Sight			Breech motion	Lock	Kind of Magazine	Number of cartridges in the magazine	Method of loading	External coil or hand-guard	Powder			Bullet					Cartridge		Initial velocity m.
									Kind	Number of notches	Maximum range m.							Kind	Form	Weight of charge g	Shape	Coating	Core	Length mm.	Weight g.	Weight g.	Number of rounds per man	
7.65	Argentina	Mauser	91	1.23	1.63	4.2	4 rightward	250	Frame	4	2000	Turn	2 front locking-lugs	Projecting, closed from below, fixed to the middle of the stock	5	Clip	Hand-guard	Guncotton	Flakes	2.68	Ogival	Nickel-plated steel sheet	Hard lead	30.7	13.7	26.8	150	630
8	Austria-Hungary	Mannlicher	95	1.27	1.51	3.5	4 rightward	250	Frame	4	1950	Straight pull	2 bolt-head tenons	Projecting, open below fixed to the middle of the stock	5	Loader	Hand-guard	Guncotton	Disks	2.75	Ogival	Steel sheet (Oiled)	Hard lead	31.8	15.8	23.68	140	620
7.65	Belgium	Mauser	89	1.27	1.51	4.0	4 rightward	250	Steps and Frame	3	2000	Turn	2 front locking-lugs	Projecting, closed from below, fixed to the middle of the stock	5	Clip	External coil	Guncotton	Flakes	2.5	Ogival	Nickel-plated steel sheet	Hard lead	30.2	14.1	28.0	120	600
8	Bulgaria	Mannlicher	95	1.27	1.51	3.7	4 rightward	250	Frame	4	1950	Straight pull	2 bolt-head tenons	Projecting, open below fixed to the middle of the stock	5	Loader	Hand-guard	Guncotton	Flakes	2.7	Ogival	Nickel-plated steel sheet	Hard lead	31.8	15.8	28.75	120	620
8	Denmark	Krag-Jörgensen	89	1.33	1.51	4.4	6 rightward	300	Frame	3	2100	Turn	2 front locking-lugs and guard-rail	Horizontal, lateral opening, fixed to the middle of the stock	5	Loading Case	External coil	Guncotton	Flakes	2.20	Ogival	Cupro-nickel	Hard lead	30.25	14.5	30.0	120	610
8	France	Lebel *	86/93	1.30	1.82	4.2	4 leftward	240	Steps and Frame	4	2000 or 2400	Turn	2 front locking-lugs	Forward in stock	8	One by One	Neither	Guncotton	Flakes	2.75 or 2.90	Ogival, somewhat flattened; or pointed	Nickel or without	Hard lead or copper	30.30 or 39.2	15.0 or 13.0	29.40 or 27.60	130 120	610 or 700
8	Germany	— Mauser	88 98	1.25 1.25	1.71 1.77	3.8 4.1	4 rightward 4 rightward	240 240	Frame Curved	4 1	2050 2000	Turn Turn	2 front locking-lugs 2 locking-lugs in front and 1 (reserve) in the rear	Projecting and open below fixed to the middle of the stock Flush and covered from below, in the middle of the stock	5 5	Loader Clip	External coil Hand-guard	Guncotton	Flakes	2.63 3.20	Ogival Pointed	Steel sheet coated with copper	Hard lead Soft lead	31.25 28.0	14.7 10.0	27.88 23.75	120 150	620 860
7.7	Great Britain	Lee-Enfield Lee-Enfield	95 05	1.25 1.12	1.55 1.42	4.3 3.8	5 leftward 5 leftward	254 254	Curved, frame and telescopic Curved and telescopic	3 2	2548 2548	Turn Turn	A locking-lug in the middle and guard rails A locking-lug in the middle and guard rails	Detachable, in the middle of the stock Detachable, in the middle of the stock	10 10	One by One Clip	Hand-guard Hand-guard	Nitroglycerin Nitroglycerin	Threads Threads	2.08 2.06	Round Round	Cupro-nickel Cupro-nickel	Hard lead Hard lead	31.88 32.10	13.82 13.86	27.40 27.48	115 100	610 605
6.5	Greece	Mannlicher	03	1.23	1.47	3.7	4 rightward	200	Quadrant	1	2000	Turn	2 locking-lugs in front	Drumlike, in the middle of the stock	5	Clip	Hand-guard	Guncotton	Disks	2.43	Ogival	Steel coated with cupro-nickel	Hard lead	31.44	10.33	22.1	?	730
6.5	Italy	Mannlicher-Carcano	91	1.28	1.58	3.9	4 rightward	Progressive 520-200	Quadrant	2	2000	Turn	2 locking-lugs in front	Projecting, open below, fixed to the middle of the stock	6	Loader	Hand-guard	Nitroglycerin	Tubes	2.25	Ogival somewhat flattened	Cupro-nickel (Oiled)	Hard lead	30.2	10.50	23.0	162	700
6.5	Japan	Arisaka	97	1.27	1.66	3.9	6 rightward	200	Frame	3	2000	Turn	2 locking-lugs in front	Flush, closed from below fixed to the middle of the stock	5	Clip	Hand-guard	Guncotton	Flakes	2.14	Slender Ogival	Cupro-nickel	Hard lead	32.60	10.50	22.41	135 †	710
7.0	Mexico	Mauser	02	1.23	1.48	4.1	4 rightward	220	Frame	2	2000	Turn	2 locking-lugs in front and 1 (reserve) in the rear	Flush, closed from below fixed to the middle of the stock	5	Clip	Hand-guard	Guncotton	Flakes	2.00	Ogival	Cupro-nickel	Hard lead	32.2	10.62	21.8	120-150	690-700
6.5	Netherlands	Mannlicher	95	1.29	1.65	4.3	4 rightward	200	Quadrant	1	2000	Turn	3 locking-lugs in front	Projecting, open below, fixed to the middle of the stock	5	Loader	Hand-guard	Guncotton	Flakes	2.45	Ogival	Nickel-plated steel sheet	Hard lead	30.92	10.2	22.81	160	720
6.5	Norway	Krag-Jörgensen	94	1.26	1.52	4.0	4 leftward	200	Quadrant	1	2200	Turn	A locking-lug in front and a guard-rail	Horizontal, with lateral opening, fixed to the middle of the stock	5	Loading frame	Hand-guard	Nitroglycerin	Flakes	2.30	Ogival	Nickel-plated steel sheet	Hard lead	32.15	10.10	23.55	150	700
6.5	Portugal	Mauser-Vergueiro	04	1.11	1.30	5.7	4 rightward	196.5	Curved	1	1800	Turn	2 locking-lugs in front	Flush, closed from below fixed to the middle of the stock	5	Clip	Hand-guard	Guncotton	Flakes	2.91	Ogival	Steel coated with Cupro-nickel	Hard lead	32.0	10.10	24.10	?	720
6.5	Roumania	Mannlicher	03	1.23	1.47	4.0	4 rightward	200	Frame	3	2000	Turn	2 locking-lugs in front	Projecting, open below fixed to the middle of the stock	5	Loader	Hand-guard	Guncotton	Flakes	2.31	Ogival	Steel coated with Cupro-nickel	Hard lead	31.56	10.33	22.72	130	710
7.62	Russia	Mossin-Nagant	91	1.30	1.73	4.1	4 rightward	240	Steps and Frame	2	1917	Turn	2 locking-lugs in front	Projecting, closed from below fixed to the middle of the stock	5	Clip	Hand-guard	Guncotton	Flakes	2.48	Ogival	Cupro-nickel (Oiled)	Hard lead	30.2	12.75	25.80	120 †	620
7.0	Spain (Brazil, Colombia, Chile, China, Uruguay, Bolivia, Orange Free State, Servia)	Mauser	93 94 95 96 99	1.23 1.23 1.23 1.23 1.23	1.48 1.48 1.48 1.48 1.48	3.9 4.1 4.1 4.1 4.1	4 rightward 4 rightward 4 rightward 4 rightward 4 rightward	220 220 220 220 220	Frame Frame Frame Frame Frame	2 2 2 2 2	2000 2000 2000 2000 2000	Turn Turn Turn Turn Turn	2 locking-lugs in front	Flush, closed from below, fixed to the the middle of the stock	5	Clip Clip Clip Clip Clip	Hand-guard	Guncotton	Flakes	2.54 From 2.45 to 2.65	Ogival	Cupro-nickel	Hard lead	30.30 From 30.25 to 30.30	11.20	From 24.60 to 24.96	From 120 to 130	Between 690 and 700
6.5	Sweden	Mauser	96	1.26	1.40	4.1	4 rightward	200	Steps and Frame	2	2000	Turn	2 locking-lugs in front	Flush, closed from below fixed to the middle of the stock	5	Clip	Hand-guard	Guncotton	Flakes	2.36	Ogival	Cupro-nickel	Hard lead	32.12	10.12	22.65	120	710
7.5	Switzerland	Schmidt	89/96	1.30	1.50	4.7	3 rightward	270	Quadrant	1	2000	Straight pull	2 locking-lugs in the middle of the lock	Detachable, in to the middle of the stock	12	Loading Case	Hand-guard	Guncotton	Vermicelli	2.0	Ogival	Steel coating, with paper-wrapping (oiled)	Hard lead	31.7	13.9	27.5	130	600
7.65	Turkey	Mauser	03	1.24	1.76	4.3	4 rightward	250	Curved	4	2000	Turn	2 locking-lugs in front and 1 (reserve) behind	Projecting, closed from below fixed to the middle of the stock	5	Clip	Hand-guard	Guncotton	Flakes	2.63	Ogival	Nickel-plated steel sheet	Hard lead	30.7	15.7	26.8	120 †	630

* For two kinds of ammunition † According to recent information the number of rounds carried by men is to be increased to 150 per man

1 meter (m.) = 39.371 inches. 1 millimeter (mm.) = .039371 inch. 1 kilogram (kg.) = 2.2046 pounds. 1 gram (g.) = 15.4324 grains = .035274 ounces.

CHAPTER II

The Characteristic Lesions Caused by Projectiles

Wounds by Projectiles from Hand Weapons.—No chapter in surgery has undergone such radical changes as that pertaining to gunshot wounds. The wounds from firearms have received benificence, like all wounds, from modern methods of treatment; but aside from this, wounds from weapons like the military rifle are not at all times so extensive in their pathological characters as they were formerly, and they are more amenable to treatment.

To understand the characteristic appearances of bullet wounds in general, we will first consider the effect of the old-time, larger, and lower velocity projectiles, as compared to those of more recent times.

The Old Round Balls.—These were usually composed of soft lead under the name of musket balls of about .72 to .75 calibers, having an initial velocity of 600 to 767 f.s. With these low velocities, spherical balls showed destruction of an amount of tissue in soft parts coincident with the diameter of the projectile. The mechanical effects of such a bullet were more that of stretching the tissues to permit the passage of the missile. The wound of entrance was round, the size of the bullet, with a punched-out appearance, and it was surrounded by a more or less extensive ecchymosis. The track of the bullet was identified by a channel of devitalized tissue greater than the diameter of the ball. The exit wound in the skin was always greater than the entrance wound, triangular or star-shaped, with everted edges having the appearance of an injury inflicted by a force exerted from within.

The effects of the old spherical bullet on bone was marked by lodgment in a large proportion of the cases, and flattening of the projectile itself. When propelled by its maximum velocity of translation, the bullet was capable of causing extensive damage, though less than that observed from the conoidal rifle bullets of a later date. The force of impact caused extensive comminution, with displacement of spiculæ about the line of flight of the bullet. Fissures were seen in the shaft above and below the area of fracture. This bone lesion, added to the

extensive trauma in soft parts, made the gunshot wounds of that era prone to suppuration and dangerous to life.

The Cylindro-conoidal Bullet.—The use of elongated bullets was coincident with the adoption of the hand rifle. The earlier types were fired from the Minié rifles, so-called, and later as the guns became more perfect, the initial velocity was increased accordingly. The accompanying chart gives the ballistic data and development stages of old-time, and modern firearms used in war.

The wounds by the elongated bullets, from the beginning, caused enormous destruction of tissue, and as the arms from which they were

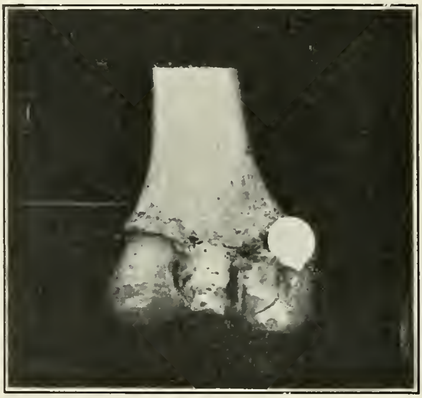
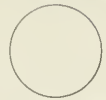
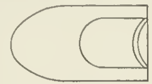
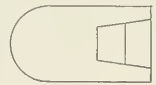
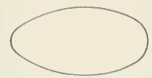
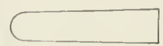


Fig. 18.—Lodged spherical soft-lead ball. Amputation lower third thigh. No. 4063 A. M. Museum. Specimen from Civil War, 1861–65.

propelled became more and more perfect, the severity of the wounds increased so markedly that accusations and recriminations of the use of explosive bullets were commonly made by combattants in the beginning of every war. The pathological appearances of a gunshot wound of the shaft of a long bone, were so much like the destruction wrought by a hollow bullet loaded with an explosive, that it was not until the mechanics of the projectiles had been properly understood that a satisfactory and convincing explanation of their effects was made.

The aim of the ballisticians, in perfecting the military rifle, from the beginning was directed toward an increase in the velocity of the projectile. This was done by accomplishing a perfect fit of the projectile in the barrel to prevent the escape of powder gases. The effect of this plan on the large calibers in use at the time of the transition,

TABLE 2.—PATTERNS AND PERIODS IN THE EVOLUTION OF SMALL ARMS

Designation	Caliber and shape of bullet	Metal	Weight bullet, grains	Powder, grains	Initial velocity, ft. sec.	Effective range, yards	Outlines of projectiles	
Smooth-bore, flint-lock musket, 1700	.7559 to .6929 spherical	Soft lead	580 to 484	354 to 277 loose black	590 to 751	164 to 328		1. Smooth-bore muzzle-loaders of this type were used with the flint-lock from about 1700 to 1840 and with the percussion-cap until rendered obsolete by the introduction of muzzle-loading rifles and elongated bullets in the Crimean War, 1854 and 1856.
Minnie-rifle, 1851........	.6929 to .6771 conical	Soft lead	686 to 555	151 black	931 to 1017	874 to 1093		2. First used in percussion-cap muzzle-loading rifles which appeared in Crimean War; used also in Italian War (1859), the American Civil War (1861–65) and by the Danish and Austrian troops in war with Prussia, 1864–66.
Enfield-rifle.............	.5708 cylindro conical	Soft lead	535	151 black	1017	874 to 3112		
Needle-gun, 1864 and 1867	.5354 oval .4842 oval	Soft lead	483 and 331	74 black	984 to 1148	1093 to 1640		3. Breech-loading rifles first appeared in the Needle-gun of the Prussians in the wars of 1864–1866. Used in Franco-German war, 1870, 71 under the name of Chassepot; by the Turks as the Peabody-Martini in the Russo-Turkish war of 1877–78; under the name of the Gras, in the Crimean war of 1891, and by the United States under the name of the Springfield rifle in all of its Indian wars from 1873 to 1893.
Chassepot, 1866..........	.4645 cylindro conical	Soft lead	385	86 black	1377	1610 to 2187		
Gras of the French, Old Mauser of Germans, etc., Springfield of U. S., 1873.	.4291 cylindro conical	Compressed lead	480 to 385	70 to 81 black	1301 to 1410	1460 to 2734		
New Mauser of Germans, Lebel of the French, Krag-Jergenson by U. S., etc., 1886–1893.	.3227 cylindro ogival	Hard lead core and cupro-nickel case	220 to 233	43 smokeless	2066	3280 to 4374		4. Breech-loading magazine rifles with reduced calibers, steel jacketed, ogival headed bullets, with smokeless powder, appeared in 1886 and later adopted by all nations. Used in South American revolutions about 1891 under name of Mannlicher, and later in the Spanish-American War 1898-Krag-Jergenson and Spanish Mauser.
The reduced caliber rifles of England, Germany, etc., U. S. rifle (New Springfield) Model 1903	.3083 pointed	Core of lead, cupro-nickel	150	47 to 50 pyro-cellulose	2700	5465		5. Breech-loading magazine rifles of reduced caliber the same as No. 4 except that the bullet is pointed in shape and known as the Bullet S. Now adopted by Germany, England and United States. First used in the Turko-Balkan War in the German Mauser, 1912–13.

from the smooth bore to rifle weapons, was to add immensely to the recoil. The latter became such a tax on the soldier's endurance that it was necessary to reduce the caliber and the amount of the explosive as well. Increase in velocity and reduction in caliber materially added to the penetration of bullets. The wounds produced in soft parts were not attended with so much contusion and laceration as with the use of the old spherical balls. The amount of devitalized tissue surrounding the track was less—the wound was more clean cut as it were.

Bone Injuries by the Cylindro-conoidal Bullets.—When a 45 caliber bullet or a projectile from any of the larger caliber rifles mentioned

Fig. 19.—Lodged conoidal ball, radiating fracture. No. 3175 A. M. Museum. Specimen from Civil War, 1861–65.

Fig. 20.—Lesion by conoidal ball. From amputated limb. No. 3245 A. M. Museum. Specimen from Civil War, 1861–65.

happened to collide with a resistant bone, like the diaphysis of the humerus or femur, the destructive appearance, as already stated, resembled the effects of an explosion having taken place from within and the pathologic condition was generally described in the literature of gunshot wounds under the term of Wounds Having Explosive Effects. The characteristic lesions were notably seen in the proximal ranges—from the muzzle up to about 350 yards. Except for close shots at contact or nearly so, the wound of entrance presented no special features. When it was located in skin overlying bone, as over

the tibia, bony sand was noted at the wound of entrance in a certain proportion of the cases. The point of impact against resistant bone showed loss of substance, the bone was finely comminuted, and radiating from this point larger spiculæ of bone, some entirely de-

Fig. 21.

Fig. 22.

Fig. 21.—Caliber .50 conoidal bullet lodged against plantar surface right foot Partial fracture of cuboid and cuneiform bones. Primary amputation by Chapart's method. Died ninth day of typhoid fever. No. 6531 A. M. M. Specimen from Civil War, 1861–65.

Fig. 22.—X-ray print of left leg of a Civil War (1861–65) veteran showing lodged large caliber, soft lead, fragmented bullet, lying between tibia and fibula anteriorly just below superior fibulotibial articulation, where it can be easily palpated. Missile entered leg posteriorly in median line of calf, about 3 inches below knee-joint and passed directly forward, apparently without seriously injuring the bones and lodged anteriorly as shown. The bullet was fragmented by bony contact in its passage through the leg. Endeavor was made on the battle field to extract the bullet by the fingers passed through the wound. Wound was infected and discharged pus for three or four months Since healing of parts there have been no symptoms of pain, atrophy, etc. Exposure made in 1912. Army Med. School collection. H. P. Pipes, Capt., Med. Corps, U. S. A. X-rayist.

tached, were driven into the soft parts in the line of flight of the bullet and at right angles to the direction of the moving body. Pulpification

of soft parts was noticed at some distance from the track of the bullet, as a result of the penetration and laceration by particles of bone, and as often happened, disintegrated particles of the bullet which, taking part of the projectiles' energy and acting as secondary missiles, added to the destructive effects. The wound of exit was irregular, and measured as much as 3 and 4 inches in its longest diameter. The space from the wound of exit to the point of impact on the bone was conical in shape, with the base of the cone correspond-

Fig. 23.—Recent skiagram in case of Maloy W. Rock, Co. "C," 1st Va. Cavalry. Shot by conoidal bullet in Civil War, 1864. Some pain in region of bullet not enough to prevent him from his usual work. X-ray Laboratory National Home for D. V. S., Marine Barracks.

ing to the wound of exit, and the apex to the seat of fracture. There was usually more or less fissuring of the shaft radiating from the fractured ends. Beyond the zone of explosive effects fragmentation was not so marked, there was absence of bony sand; the fragments were not so much displaced. The wound of exit was, however, perceptibly larger than the wound of entrance and this fact was, as a rule, a pretty sure indication of bone lesion.

When the conoidal bullets happened to collide with the *epiphyseal ends* of the long bones in the proximal ranges the softer bone was broken into many fragments, with less tendency to displacement of fragments than noted in the more brittle osseous structures. There

was more bone dust and greater tendency to entire loss of substance at the point of impact, with little or no fissuring of the shaft. At longer ranges—500 to 1500 yards—the bullets showed a tendency to perforate the epiphyseal structure with no splinters nor fissures resulting. The pathologic lesion was a complete perforation, resembling a hole made by a drill. The cause of the difference in the lesion noted between the

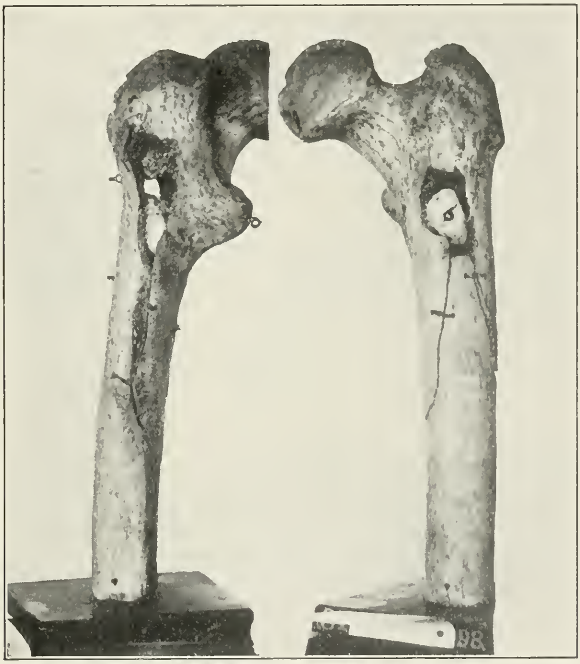


Fig. 24.—Anterior and posterior views. Fracture at base of trochanters. Note long fissures. Lodged deformed conoidal ball. No. 87. A. M. M. Specimen from Civil War, 1861–65.

middle of the shaft and the joint end of a long bone lay in the degree of resistance offered—the bone of the shaft being hard and more brittle, that of the epiphysis being soft and spongy.

The amount of destructuve effects in bone was always coincident with (a) resistance on impact, (b) sectional area of the bullet and (c) its velocity. The theories advanced to explain these so-called explosive effects will be taken up later.

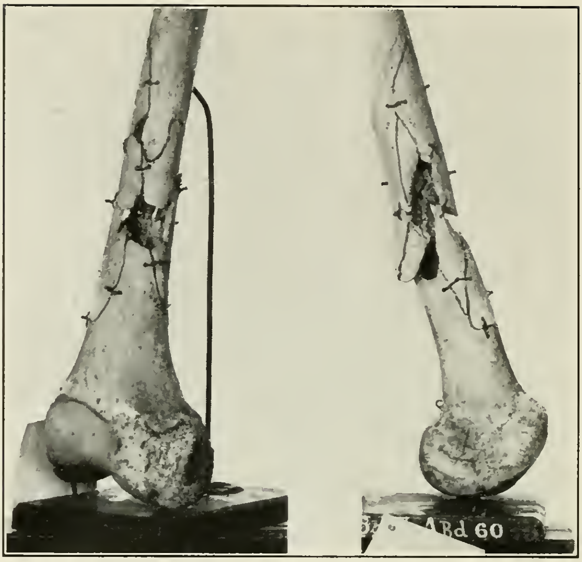


Fig. 25.—Anterior and posterior views of fracture right femur from conoidal ball. Amputation third day; died nineteenth day. No. 2056 A. M. M. Specimen from Civil War, 1861–65.

Fig. 26.—Perforation by musket ball of epiphyseal end right femur with long fissures in shaft. Limb amputated; death on fourteenth day. No. 76, A. M. M. Specimen from Civil War, 1861–65.

Injuries by Steel Armored Bullets from Reduced Caliber Rifles.—Our first knowledge of the effects of steel-clad bullets came to us from certain experiments. The experimenters were at the onset confronted with the difficulty of hitting one particular anatomical part—the femur or tibia for instance—at anything like battle ranges. Obviously experiments at the actual ranges must have consumed much time and material, and observers in the experimental field followed the plan, which is common with gun makers in like cases, of employing simulated ranges, *i.e.*, by regulating the charge in such amount as to confer the remaining velocity which might be required at any given distance. In a series of experiments which we conducted at Frankford Arsenal, Philadelphia, in 1893, we fired into cadavers at a fixed distance of 53 feet, and from this distance, by graduating the charge, we were able to note the effects of bullets on different parts of the human body at all ranges from 100 to 2000 yards.

The results which were thus obtained were subsequently criticised from many quarters. It was claimed that the experimental shots against bone and closed cavities containing fluid contents gave exaggerated results as compared to what was seen in war subsequently. Some of the critics attributed these discrepancies to the use of dead tissues as compared to the effects of the same projectiles on the living, and, again, it was claimed that the velocity of rotation of the elongated bullets was different in the shots at simulated ranges as compared to what it would be at normal ranges.

In addition to our own experiments with this method, Delorme and Chavasse in France, Kocher at Berne, Paul Bruns of Germany, and others, employed the method which we pursued. The conclusions arrived at independently by the experimenters were, generally speaking, about the same. They related principally to the humane features of the wounds caused by the new bullet on some tissues, and the explosive effects noted on others, but, generally speaking, the bullet was looked upon as likely to play the part of a humane instrument in the wars of the future.

Later, Demosthen, Von Coler, Schgerning and others shot into cadavers with full charges at actual ranges and they arrived at different conclusions to those of the observers who had shot at similated ranges. They claimed that the explosive effects at the proximal ranges were less with the use of normal charges, and that the destructive effects became perceptibly less as the range was increased.

In recent years the results from the Spanish-American, Boer, Russo-Japanese and the recent Turko-Balkan wars have come up for

comparison with the work of the experimenters. The war wounds are thought by some critics to be but little different to those obtained from experimental shots, while quite a number of the critics arraign the expermienters who would use simulated methods on *putrid flesh* as rank exaggerators. We will endeavor to show that the work of the experimenters was not done in vain. By comparing photographs, dissections, and skiagrams of gunshots on cadavers at simulated ranges with similar illustrations obtained in recent wars, we hope to show that the conclusions of the experimeters were in the main correct.

While visiting at Val de Grace one day in 1900 the writer saw an improvised target in a corner of the enclosure. He afterward saw a student dissecting a gunshot fracture of the tibia in a cadaver and on inquiry he was told by Surgeon General Dujardin Beaumetz that the method of firing into dead bodies for the purpose of teaching the effects of gunshots in war had been practised in the French Army for one hundred years. Surgical literature gives the French Army surgeons the front rank as writers on Military Surgery, and it is not reasonable to suppose that close observers, such as they have shown themselves to be, could pursue a method so long when, as some critics would have us believe, there is nothing to be learned from it.

We are willing to concede that a dead body half frozen out of cold storage, hardened in pickle; or, a fleshy body, stiff in rigor mortis, will give exaggerated results in shot fractures of the diaphyses of the long bones. The rigid or plastic flesh offers more resistance and the wound of exit is doubtless larger and more lacerated, but in fit subjects, the effects on bones, the head, the chest, abdomen and vessels will compare with those on the living sufficiently to enable one to formulate conclusions that in the main are correct. The class in operative surgery in the U. S. Army Medical School is made to amputate for gunshot fractures and to examine by dissection the lesions in gunshot injuries in various parts of the dead body. This part of the work is always compared at the time with the X-ray findings which have been previously made in each case.

From observations and experience off and on in the last twenty-one years by firing experimentally into cadavers, animals, and inanimate matter, and later from opportunities which have come to us to see the comparative effects of the old and new armaments on the living in peace and war, we believe that the experimental way is the best method of teaching the mechanical effects of projectiles on tissues in times of peace at least, and that it answers as a valuable guide to a correct understanding of the gunshot injuries observed in war.

Our experiments at Frankford Arsenal were conducted under orders of the War Department dated July 20, 1892. A board of officers was appointed of which the writer was the medical member, to ascertain the "effects of small arms firing with new calibers and velocities on the human frame." In order to make the results more apparent, the board followed the plan of—

(1) Noting the effects of a projectile of larger caliber and lower velocities upon different parts of the human body at various ranges.

(2) Noting the effects of the projectile of a reduced caliber rifle, having greater velocities, upon similar parts of the human body or parts offering about the same resistance at similar ranges.

The larger weapon selected was the .45 caliber Springfield rifle which had formed the armament of our foot troops since 1873 and which compared as to caliber, weight of ball, charge of powder, and ballistic details to the Gras, old Mauser, and the military rifles of the nations before the introduction of the new armament.

The smaller caliber weapon furnished the board by the Ordnance Department was known as the Experimental Springfield rifle, caliber .30. Its bullet was impressed by 37 grains of Payton smokeless powder. This gun compared favorably with the rifles of reduced caliber in use at that time by Germany, France and Austria, viz., the Lebel, New Mauser, and Mannlicker.

The more important ballistic values of the two weapons are set forth in the following tables:

VELOCITIES OF THE PROJECTILES OF THE TWO GUNS

Name and caliber of weapon	Initial velocity	500 yards	1000 yards	1500 yards	2000 yards
	f.s.				
Springfield, caliber .45	1301	873	676	531	429
Experimental Springfield, caliber .30	2000	1103	804	627	495

A tackel was provided to suspend the cadavers and to bring the portion of the body to be fired at into proper position. Each projectile was stamped at the base with a letter or number for identification and all bullets were collected from barrels of sawdust placed behind the target. Ten years after the termination of these experiments we went

ENERGY OF THE PROJECTILES
(In foot-pounds)

Name and caliber of weapon	Initial velocity	Weight	Muzzle	500 yards	1000 yards	1500 yards	2000 yards
	f.s.	Grains					
Springfield, caliber .45......	1301	500	1879	846	507	313	204
Experimental Springfield, caliber .30.	2000	220	1954	594	315	192	120

to war with Spain; the wounded from this war gave the first opportunity of any consequence to military surgeons to observe the effects of reduced caliber bullets on the living. Before this we had depended upon accidents, suicides and reports from some of the South American revolutions, but the latter especially were meager and unreliable. In the battle of Santiago the United States troops engaged numbered about ten thousand men, those of the enemy approximately the same. Our casualties were 233 killed and 1400 wounded. Having taken active part in the experimental work already referred to, the writer was necessarily very much on the alert to compare the wounds on the living in war with those he had so often witnessed on the dead in peace. We had occasion at this time to review our own conclusions, and those of other experimenters, with the experience culled in and after the battle of Santiago. The conclusions of the experimenters are 12 in number, and they appear in quotation marks with a running comment, as follows:

(1) The experimental evidence showed that "the shock impressed upon a member increases with the velocity, whether a bone is traversed or not. It is always greater with the larger caliber leaden projectile." This diminution in shock has been one of the serious objections advanced against the adoption of the small bullet by military men. They feared that one wound would not suffice to throw a man *hors du combat,* and that he might be able to go on fighting regardless of the fact that he had been hit a number of times. Whether this is true of savage tribes, or horses in a cavalry charge, it is not true of our American soldiers. Upon inquiry among line officers in the Santiago campaign, we learned that, as a rule, to which there were very few exceptions, men when hit fell back to the rear at once; and we can

testify to the fact that scores of them walked back to our hospital at Siboney, with wounds that were most trifling in their nature.

(2) "The explosive effects at very short ranges are about the same for the two projectiles and they continue so up to about 350 yards." We only saw one case which approached anything like explosive effects in Cuba. That was the case of a captain of the rough riders, shot in the lower third of the tibia. The wound of entrance was about the

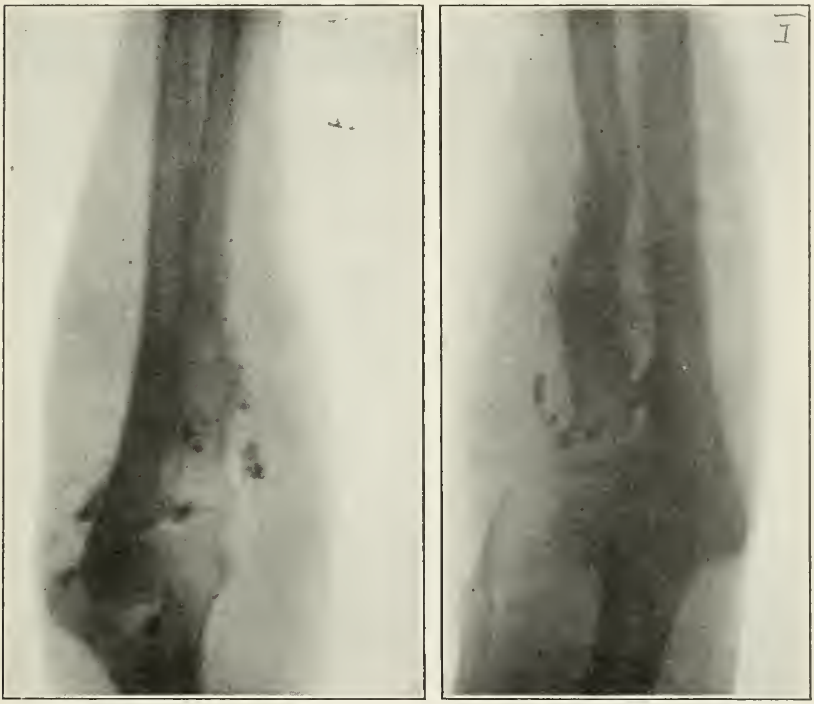


Fig. 27.—Two views of explosive effects from Mauser bullet at close range at battle of Santiago. Radiograph one year after injury. Army Med. School collection.

caliber of the Mauser bullet that had inflicted it, and the wound of exit was irregularly round, a half-inch in diameter. There were two smaller wounds near the wound of exit, which were undoubtedly made by spiculæ of bone which had been driven forth, acting as secondary missiles. The area of fracture was about 4 inches above the ankle; it was marked by a cavity in which many loose fragments of bone lay, none of them measuring more than a half-inch. The wall of the cavity

showed bony sand driven into the soft parts. The infrequency of explosive effects among the wounded at the battle of Santiago should

Fig. 28. Fig. 29.

Fig. 28.—Photograph of a butterfly fracture of tibia; experimental specimen from cadaver by the reduced caliber bullet at 1200 yards. The fissures were mostly superiosteal in recent specimen. Army Med. School collection.

Fig. 29.—(1) Guttering of tibia and transverse fracture from vibratory force by reduced caliber bullet at 1200 yards. Experimental specimen, from cadaver. (2) Complete perforation of lower epiphyseal end of tibia with slight fissuring, same ammunition as No. 1 and at the same range. Bullet replaced in perforation by photographer. Army Med. School collection.

be attributed in our opinion (a) to the fact that the vast majority of the wounds were inflicted beyond the zone of explosive effects, and (b)

since explosive effects are chiefly to be noted in the vital parts contained in rigid walls, like the brain, or in those organs containing much fluid, like the heart, liver, spleen, the alimentary tract, these wounds with explosive effects, so destructive to tissue, were numbered among the dead—a class which, unfortunately, the surgeon has no time to study on the battle field (Fig. 27).

(3) The experimenters found that "the smaller frontage of the jacketed bullets causes them to inflict injuries resembling subcutaneous wounds when the soft parts alone are traversed, and that the small

a b

FIG. 30.—Photograph of perforation in head of tibia by .30 cal. German silver-jacketed bullet, shot out of the experimental Springfield rifle, into a cadaver at a simulated range of 1200 yards by the author. Bullet used is undeformed and shows to left of specimen. (a) Orifice of entrance; (b) orifice of exit. Army Med. School collection.

wounds of entrance and exit and the narrow track of the missiles were favorable circumstances to rapid healing." The truth of this statement is borne out by the experience of all surgeons in the Santiago campaign. Flesh wounds healed very kindly and rapidly.

(4) This conclusion of the experimenters refers to hemorrhage. Johann Habart, of the Austrian Army, who paid special attention to this subject, states "that the blood-vessels are seldom torn by the

small jacketed bullet, and that when wounded they are not closed so easily by coagulation as those severed by leaden projectiles." Some writers have deduced from this statement that alarming or fatal hemorrhage would be more frequent in future battles. The experience of the surgeons with the line before Santiago does not confirm these apprehensions. Of the 1400 wounded as far as we could learn, not one died of external hemorrhage. The brachial and femoral were tied a few times in the base hospitals for diffuse aneurysm. One case of wound of the subclavian was operated upon in New York and died and there

Fig. 31. Fig. 32.

Fig. 31.—Front view. Radiograph in case of W. K. showing perforation of upper end of tibia. Wounded June 25, 1899, by a Krag-Jorgensen bullet at a distance of 10 feet. Radiograph taken 30 months after injury. Remote effects: slight weakness and pain at site of wound. Good motion in joint. U. S. Soldiers Home collection.

Fig. 32.—Skiagram showing side view of Fig. 31.

were five cases of gangrene from injury to blood-vessels which required amputation.

(5) "Injuries inflicted outside the zone of explosive effects upon the shafts of the long bones always show less comminution with the small bullet of hard exterior. The fissures are often subperiosteal, and the fragments are larger." This was true of the Mauser bullet wounds in Cuba. It was seldom necessary to open up the wounds for the purpose of taking out loose fragments of bone. In a number of instances there was distinct guttering of the compact substance of long bones

without fracture. The mobility in some instances was so slight that it was difficult to make out a complete fracture when from the location of the wounds it was certain that the bone had been traversed.

(6) "Beyond the zone of explosive effects the projectiles of hard exterior almost invariably perforate or gutter the joint ends of bones, and the lesions of the articulations are never so grave." This conclusion tallies exactly with what we saw in Cuba. We do not recall a

Fig. 33.—Exit wound showing explosive effects on bone by Japanese rifle bullet at short range. Russo-Japanese War. (Lynch.)

formal excision of a joint for the mechanical effects of the Mauser bullet. Joints were opened to turn out blood clots, and in one instance of the knee we particularly remember, to locate a lodged ball, but never for the purpose of performing an excision. There were seventeen cases of gunshot injury to the knee-joint. These were immobilized and shipped north; and 82 per cent. of them were restored to duty within a few months. These results are a great contrast to gunshots inflicted by the larger leaden bullet, which by its highly destructive effects must have caused a number of partial resections and amputations.

(7) "The projectiles of hard exterior lodge less frequently in the tissues than the old leaden bullet." The experience at Santiago,

among the wounded of both sides, has shown a surprisingly large number of lodged balls. Although we are not prepared to state that the small-caliber bullet lodges as often as the old discarded leaden bullet, the frequency with which it did lodge was commented upon by all of our military surgeons. Dr. W. E. Parker, of New Orleans, an acting assistant surgeon in the base hospital, visited the Spanish hospitals in Santiago after the surrender, and in conversation with the Spanish surgeons he learned that our Krag-Jorgensen bullet had not lodged in their wounded as often as their Mauser bullet had lodged in our men. The explanation for this would seem to be simple enough. It should be remembered that we were on the aggressive in a region that was practically unknown to our troops, while the Spaniards were perfectly familiar with every foot of ground over which we must make the advance. As trained soldiers, their officers had carefully studied the range at every point. With this valuable information in their favor they were in a position to commence an effective fire at remote ranges, say at 2000 yards and more. We could not locate them as soon as they located us, and when we did locate them, we had to study the range before we could commence an effective fire. It was while we were locating them and studying the range and gradually advancing that they placed so many balls into our soldiers. When we did commence an effective fire, we had reached a point where the remaining velocity of our bullet on impact was sufficient to carry it through the body. There is another explanation which might be attributed to the difference in the energy of the two bullets at remote ranges. Our bullet being larger and heavier than the Mauser has greater energy at 2000 yards, and it will penetrate farther in the remote ranges than theirs. Again, ricochet shots, from the thick underbrush and broken ground, undoubtedly favored a certain percentage of lodgments. Many of the officers attributed the lodgment of projectiles to the use of defective ammunition used by the enemy. This point was so susceptible of proof that we instituted experiments to show the relative penetration of the Mauser and Krag-Jorgensen rifles. The tests were made in large blocks of well-seasoned yellow pine fired into, across the grain, 3 feet from the muzzle. The penetration of the Krag-Jorgensen ammunition was 24 inches plus, while that of the Mauser ammunition exceeded ours by nearly 10 inches, a demonstration which at once set at rest the idea of lodgment from the defective ammunition of the enemy.

(8) "The old leaden bullet more often leaves fragments of lead in

the foyer of fracture." This is so true that it needs no contradiction. The leaden bullet was so soft that it often separated into a number of fragments upon striking resistant bone, while the steel-jacketed bullet, as is well known, seldom encounters resistance enough in the human body to disintegrate it.

(9) "As the projectiles of smaller caliber are less apt to lodge or to carry foreign substances into the wounds, we will expect to find fewer cases of suffering due to the remote effects of unextracted foreign bodies." This is true of the smaller bullet, as shown in Cuba. There were but few instances where clothing or part of the equipment was carried into the wound.

(10) "The frontage of the jacketed bullet being much less and the fact that it does not lodge as often as the larger leaden bullet will serve to increase the percentage of recoveries in gunshot wounds of the lungs." That was especially true of the wounded in Cuba. As a rule the wounds of the lungs were apparently so trivial that it was difficult to restrain the men in the recumbent posture.

(11) "Owing to diminished frontage the new bullet will cause less disfigurements in wounds of the face." That was especially true of three officers who received painful wounds of the face.

(12) "The projectiles of hard exterior are more humane than the old, resections and amputations will not be so often required hereafter, soldiers will be more often restored to the State useful members of the community instead of cripples and pensioners, and in point of economy, the new projectile will confer a great advantage." This last conclusion is also in accordance with the experience in Cuba. There were but three primary amputations and not one of them was done for injury by the small bullet. They were all the result of shell injuries. From the foregoing we believe that the work of the experimenters agrees with the conditions found in war, and that their work was not done in vain. Furthermore, we may state that we are not acquainted with any experimenter who is ready to repudiate his work as futile.

SOME FURTHER OBSERVATIONS ON WOUNDS BY MILITARY RIFLES IN RECENT WARS

In the Spanish-American War the Spaniards were armed with the Spanish Mauser of 27.6-inch caliber, weight of projectile 172 grains, with ogival head, and a muzzle velocity of 2296 f.s. The United

States troops were armed with the Krag-Jorgensen rifle, of .30-inch caliber, weight of projectile 220 grains, with ogival head, and initial velocity of 2000 f.s. In the Boer War the latter were armed principally with the Spanish Mauser, whose features are like those mentioned above, some Krag-Jorgensen and Martini-Henrys, but the bulk of the wounds came from their service weapon, the Spanish Mauser. The British troops used the Lee-Enfield of .303 diameter, with a muzzle velocity of 2060 f.s., weight of projectile 215 grains. In the Russo-Japanese War the Russians were armed with the Mossin-Nagant of .30-inch caliber, with a muzzle velocity of 1985 f.s.; weight of projectile 214 grains. The first and second lines of Japanese troops were armed with a more perfect type of gun as follows: the Arisaka of 25.6 caliber, muzzle velocity 2390 f.s., weight of projectile 162 grains. The rest of their army was armed with a gun which corresponds to our Krag-Jorgensen of ten years ago. In the Turko-Balkan War of 1912–13, the Balkan states were armed with the Mannlicher rifle of reduced caliber which about corresponds to our Krag-Jorgensen rifle with the ogival-headed bullet used by our troops in the Spanish-American War. The military rifle of the Turks was the German Mauser, which fires the pointed bullet. This projectile was recently adopted by the English and U. S. Armies. It was never used in campaign until the recent war between Turkey and the Balkan States.

It will be seen therefore that the hand rifle of the combatants of all armies except the first and second lines of Japanese troops and the German Mauser of the Turks which fired the pointed bullet were the same in ballistic value. Taken as a whole there was no difference in the penetration or smashing effects of the bullets worthy of consideration with the possible exception of the 162-grain bullet of the Japanese Army, which was more humane and the pointed bullet of the Turks, in the recent Turko-Balkan War whose deadly effects will be commented upon later.

Wound of Entrance.—With high velocities the wound of entrance is apt to be larger than we find it at mid and remote ranges. The wound is round when the bullet strikes perpendicularly, and oval if it impinges obliquely. The regularity of the circle or oval is seen oftener in skin that is well supported. Entrance wounds in skin overlying bone as that over the sacrum, anterior part of tibia, and sternum, are larger than the projectile. In skin overlying loose areolar tissue like the scrotum, the entrance wound is less regular, slit-like, and apparently smaller than the diameter of the bullet. When

by ricochet or otherwise the bullet strikes side on or "butt end to" the entrance wound is irregular and lacerated. The edges of the wound are apt to be inverted or depressed for a short time, and covered with a dark gray substance, more than likely dirt, resulting from the gases of explosion. Underneath the dark stain appears the pink cuticle denuded of epithelium, by the friction of the projectile. This pink rim soon dries and turns brown in color. Slight ecchymosis appears later about the entrance wound, but it is never so well marked as in the case of the older and larger caliber bullets.

Wound of Exit.—These wounds are more variable in extent and shape than the wounds of entrance. Again with maximum velocities, provided no bone lesion is present, the exit aperture is often difficult to discriminate from the entrance wound. The two wounds may be equal in size, the entrance wound may show inverted edges, while in the exit wound the edges are generally everted. When the bullet has passed through soft parts alone, the exit wound is apt to be circular in shape. In loose skin, with low velocities, the exit wound is apt to be lacerated, and when the velocity is high it is apt to be marked by a mere slit. The greatest extent of traumatism with maximum irregularity is seen in exit wounds following bone lesions. The lesion of hard bone, like the diaphysis at close range, shows maximum wounds of exit. Such wounds present typical explosive effects. The exit wound in the skin may be several inches in diameter.

With the high-power military and sporting rifles the track of the bullet is marked by a straight line connecting the entrance and exit wounds when the parts have resumed the position of the body at the time of the shooting. The new bullet is seldom deflected. It goes in a straight line from the point of impact in the skin to the point of lodgment, or exit from the body. The bullet cuts a channel through soft parts, like muscle, the size of its own caliber or a trifle larger. The cylindrical track and the surrounding tissues are marked by the presence of hemorrhage, contusion, and engorged vessels. Perforations in tendons and resistant fasciæ are marked by circular or slit-like openings. When projectiles from richochet, or extended range, lose their balance, tendons may be torn across or lacerated as a result of keyholing.

Foreign Bodies Carried in Wounds.—On account of the smaller frontage of the new military rifle bullet, particles of clothing, or part of the equipment of soldiers are not so often driven in wounds as they were by the projectiles of the larger caliber armament. Our ex-

perience in Cuba and those of Makins, Stevenson and others in recent wars fully confirm this statement. The old-time larger caliber and lower-velocity projectiles carried foreign matter in wounds that proved a fruitful cause of prolonged suffering among the wounded. Among the particles carried in with the balls were portions of cotton and wool clothing, fragments of various articles found in the field kit of soldiers; also, coins, pieces of keys, watches, etc., carried in the soldier's pockets. Longmore even mentions bits of leather from boots, shoes, pouches, etc.; buttons, nails from shoes, buckles and other metallic substances which have from time to time been extracted from body wounds in the wars of the past.

Injury to Blood-vessels.—As we have stated elsewhere injury to blood-vessels turns out to be one of the chief characteristic lesions of the new bullet. The projectile cuts the side of a vessel, or scoops out a hole in a large vessel, like a cutting instrument, leaving a band on each side of the openings. The cut edges are not lacerated and external hemorrhage or more frequently internal hemorrhage takes place at once. In the body cavities the hemorrhage is alarmingly fatal. In limbs or parts where the vessel is well supported by surrounding tissue, aneurysm is apt to follow. Vessels are no longer pushed aside as they were by the older lower-velocity bullets.

Injury to Bone.—According to Fischer's well-known statistics 22 per cent. of all gunshot wounds in war involve fractures of the long bones. Although his statistics were gotten out before the advent of the new armament we know that they are about the same for the wars of the present. A study of the effects of the new arm on the diaphyses of long bones of the extremities confirms entirely the work of the experimenters. The Spanish-American, South African, and Russo-Japanese wars have given abundant evidence of the destructive effects of the small bullet on the compact substance of the long bones. These effects are magnified at short ranges or when the velocity is high.

In our experiments referred to, we[1] called attention to perforations in diaphyses with subperiosteal fractures, which were incomplete, and to the great necessity of handling such bone lesions with care in order to prevent complete solution of continuity. Such lesions are more often seen in mid-range shots. This condition of perforation in the compact substance of a long bone has been noted in recent wars and it is to be accounted for as it was explained in the dissecting room by us, on the ground that bones are not of uniform resistance, the bones

[1]Annual Report Surgeon General, U. S. Army, 1893.

of the young have more animal matter and they will sustain an injury which will simulate a perforation, while the bones of the older subjects have more mineral matter and being more brittle, they will show comminution by preference.

Some observers have expressed surprise that extensive comminution should take place in the latter end of the trajectory, at say 2000 yards. This is true in war on the living and true of experimental shots on the dead. Up to 350 yards the destructive effect of the larger caliber lead bullet and the small-jacketed bullets are alike severe. Unless guided by the wound of entrance or other circumstances it is difficult within this range to determine by the appearance of the external wounds alone which of the projectiles may have caused the injury. Beyond this range the destructive effects of the smaller projectile become less than those of the larger missile. The fissuring is less, the spiculæ of bone are larger, and they are more apt to be attached to the periosteum. These differences are especially noticeable from the 500 to the 1500 yard ranges. At 2000 yards the small bullet again shows rather extensive comminution. This fact has been noted by all observers, and it has been variously explained, though not in a very satisfactory manner. It has been said that the projectile has lost so much of its velocity of translation when it reaches this part of its course that it is apt to lodge, and that the velocity of rotation causes such a disturbance when it is about to engage that comminution is the result. The angle of impact, which is rarely perpendicular at this range, has also been brought forth as a possible cause. Certain it is that a number of the projectiles were observed at this range by us to impinge side on at the moment of impact. The results in recent wars tally with those observed by experimenters. Exaggerated destructive effects have been reported at 2000 yards or more, and they are most likely the effects of lateral pressure from tangential shots.

Injury to the Epiphyseal Ends of Bones.—The results in all of the recent wars give convincing evidence of clean cut perforation with little or no fracture in nearly all cases of injury to the joint ends of bones. This is due to the fact that the bone in the epiphysis is soft and offers but little resistance, compared to that in the diaphysis. Unlike the lesion in the diaphysis the extent of injury is uninfluenced by velocity. Even close shots will show perforation, in the head of the tibia for instance, with little or no fragmentation. Perforations

are not confined to jacketed bullets; they were sometimes seen with the use of the larger elongated lead bullets. The uniform perforation of the epiphyses of bones from the new bullet has contributed more than any of the characteristic effects of the new armament to make the wars of the present more humane.

Injuries to the Head.—A study of close shots in the living such as have been noted repeatedly from suicides shows the wounds of the cranial vault to be typical of the class known under the name of *Explosive Effects.* In such cases extensive fissures radiate toward each other from the points of entrance and exit; fracture of the base through the sphenoids and temporal bones are not uncommon, and instances are described in which the skull-cap and the skin covering it have been literally torn away. The observations that have been made among the dead and those who have lived to reach the field hospitals in recent wars show that at battle ranges even, the amount of comminution and fissuring of the bones of the skull is great. This was particularly so among those we saw at Santiago.

EFFECTS OF THE POINTED BULLET OR BULLET "S" OF THE GERMANS

A change is about to take place in the shape and weight of the bullets of the military rifles for all armies that deserves consideration at this time. This bullet is popular with military men because it has a flatter trajectory, and longer danger zone than any of the reduced caliber bullets tried so far. Such a bullet has recently been adopted by England, Germany, Turkey and the United States. The one adopted by this country has a pointed instead of an ogival head. It is 1.08 inches in length; .3083 inch in diameter; weight 150 grains; the jacket is composed of cupro-nickel steel. The velocity of translation is 2700 f.s. at the muzzle, and the velocity of rotation 3240 turns per second as it issues from the weapon. The point blank range firing standing is 718.6 yards. The center of gravity of this bullet is disposed well toward its base. Experiments which we have made on cadavers demonstrate that the bullet is poorly balanced and that the slightest amount of resistance will cause it to turn on its short axis. The resistance in the hip-joint, the chest, and abdominal walls caused the bullet to turn in nearly every instance, as shown by keyholing in the head of barrels of sawdust immediately behind the target, and the

resulting wounds were comparable to those inflicted by an expanding bullet. (See Figs. 34 and 35.)

Doebbelin[1] reports probably the first case of a wound by the "S" bullet, which corresponds to our pointed bullet, in a soldier who was shot twice in the back, by a sentinel at 25 meters distance, as he was attempting to escape. There were two wounds of entrance about the size of a lead pencil. The first was located opposite the tenth rib

Fig. 34.—Experimental shot in cadaver. Keyholing of pointed bullet in blotting paper behind target after going through hip-joint at a simulated range of 100 yards.

near the right axillary line; the second was located 9 cm. to the right of the base of the coccyx. The wounds of exit were both large. The upper being about the size of a fifty-cent piece on the line of the right nipple, shattering the eighth rib, making a cavity at the point of fracture the size of a fist. The lung was uninjured. Wound of exit contained splinters of bone. The lower wound of exit was the size of a silver dollar containing bone splinters and a fragment of the bullet which was located 4 cm. below the crest of the right ilium near the anterior superior spine. After opening the abdomen the diaphragm was found lacerated from its attachment to the anterior wall of the

[1] Deutsche Mil. Aertztl. Ztschr., Berlin, 1906, XXXV, 625–628.

chest, and the bullet causing the upper wound had plowed through the dome of the liver making a channel 15 cm. long and 5 cm. in diameter. The intestines were not injured. A tampon was placed in the liver wound and the abdomen sewed up, leaving a drainage tube. The patient was discharged from hospital on the eighteenth day cured. Fig. 36 shows the effects of the U. S. Army pointed bullet on the femur at close range.

Fig. 35.—Explosive effects in right thigh of a cadaver due to pointed bullet shot out of U. S magazine rifle at simulated range of 100 yards. Entrance wound round, size of bullet. Exit wound 6 inches long, by 3 inches wide; opening large enough to admit fist. Bullet hit femur in middle third causing extensive fragmentation and it then struck head of barrel behind the target, side on. A. M. School collection.

Hunters[1] after large game have noticed the keyholing of the pointed bullet in soft and resistant parts alike, and the slashing effects are reported to be great. Col. Roosevelt in his African Game

[1] Stewart Edward White and Chas. Newton in "Arms and the Man," June 1, 1911.

Trails[1] states that the Winchester 405 and Springfield cal. .30 were the weapons, one of which he always carried in his hand, and he adds "for ordinary game I much preferred them to any other rifles." At 280 and again at 180 yards, the full-jacketed sharp-pointed Springfield rifle bullet brought down two Eland bulls, each with one shot, as heavy

FIG. 36.—Pvt. E. S., C. A. C., U. S. A., a prisoner, attempted escape from guard at Ft. Wayne, Mich., May 17, 1909. Shot with .30 cal. Springfield rifle using the service cartridge of 1906 ammunition, pointed bullet.

On entrance to hospital patient was in state of shock. Wound entrance 1 inch to right and 1 inch above anus size lead pencil. Wound exist at outer border of right thigh just below great trochanter 3 inches by 3 inches in diameter and greatly lacerated, filled with broken bone. The whole hip presented a greatly contused aspect. Further examination revealed compound comminuted fracture of right femur just below great trochanter. An extensive area of loose bone was plainly palpable.

Subsequent history of case marked by suppuration, secondary operation for necrosis, and 3 1/2 inches shortening with complete use of leg. Exposure made in 1910.

Reported by Major D. C. Howard, Med. Corps, U. S. Army.

as a prize steer, the bullet making "a terrific rending compared with the heavier ordinary shaped bullet of the same composition." For heavy game like rhinos and buffaloes he personally preferred a double barreled Holland 500–450. An examination of some heads of hippos and rhinos in the new National Museum at Washington shows remarkable crashing effects of the soft-nose bullet of the latter rifle against

[1] African Game Trails by Theodore Roosevelt, pp. 141–142 and 190–191.

thick resistant bone. Col. Roosevelt[1] again informs us that at 350 long paces he brought down a hyena "with its throat cut, the little sharp-pointed full-jacketed bullet makes a slashing wound." At 360 yards while shooting against giraffe he states that "the sharp-pointed bullet penetrated well without splitting into fragments, causing a rending shock." The same reports come to us from isolated cases of injury upon the natives by the new pointed bullet in the Philippines. The effects of the pointed bullet in the Turko-Balkan War of 1912–1913 have sustained the estimates of the experimenters as to its degree of deadliness. The body wounds in the two belligerent armies seldom lived to receive hospital care. The high ratio of wounds by shrapnel which in themselves cause an excessive mortality among body wounds have come in to mask the deadliness of the pointed bullet, but the reports of all the observers are unanimous on the field mortality. Major P. C. Fauntleroy, M. C., U. S. Army, our attaché with the armies in the field from Jan. 1 to March 15, reports the approximate total casualties in the Bulgarian Army as follows:

FIG. 37.—Photograph showing Turkish cartridge and bullet used in Turko-Balkan War.

	Killed	Wounded	Died from wounds
Officers..........	400	1,000	300
Soldiers..........	23,000	55,000	10,000

About 20 per cent. of all wounds were from shrapnel.

If we add the number of officers and men killed and wounded, we find the ratio of killed to wounded to be 1 to 2.5. The very few abdominal wounds that lived to reach hospital care were prone to develop localized septic peritonitis with abscess. Penetrating chest wounds by the spitz-ball, as the pointed bullet is called over there, were prone to the development of complications like pneumo-hemothorax, pyothorax, etc. Of the wounds by the spitz-bullet that reached hospital care, the majority were not serious and recovery occurred in

[1] Op. cit., pp. 197–198 (2), 205.

from four to six weeks. Much to the surprise of the observers the pointed bullet often lodged. This was attributed erroneously to defective ammunition.

With simulated velocities at 800 to 1000 yards the bullet in our experiments already referred to showed great tendency to lodge upon striking against compact and cancellous bone tissue. The field surgeons in the Turko-Balkan War also reported its lodgment most gen-

FIG. 38.—Skiagram of fractured humerus with explosive effects by Turkish bullet at battle of Lulu Bergas, 400 meter range.

erally at 800 to 1000 meters, especially when resistant bone was hit, and they saw explosive effects at short ranges when resistant structures were traversed.

It requires no prophet to predict that the war wounds of the future will be much more grave. Body wounds will be more uniformly fatal; injury to bone will be more extensive and prone to suppuration. The humane character of the reduced caliber bullet wounds so happily noted in recent wars will be less frequent. This

will be especially true of wounds of the lungs and epiphyseal ends of bones.

The following skiograms and photographs from the Turko-Balkan war of 1912–13 were presented to the War College Library by Major P. C. Fauntleroy, M. C., U. S. A. (Figs. 38 to 47).

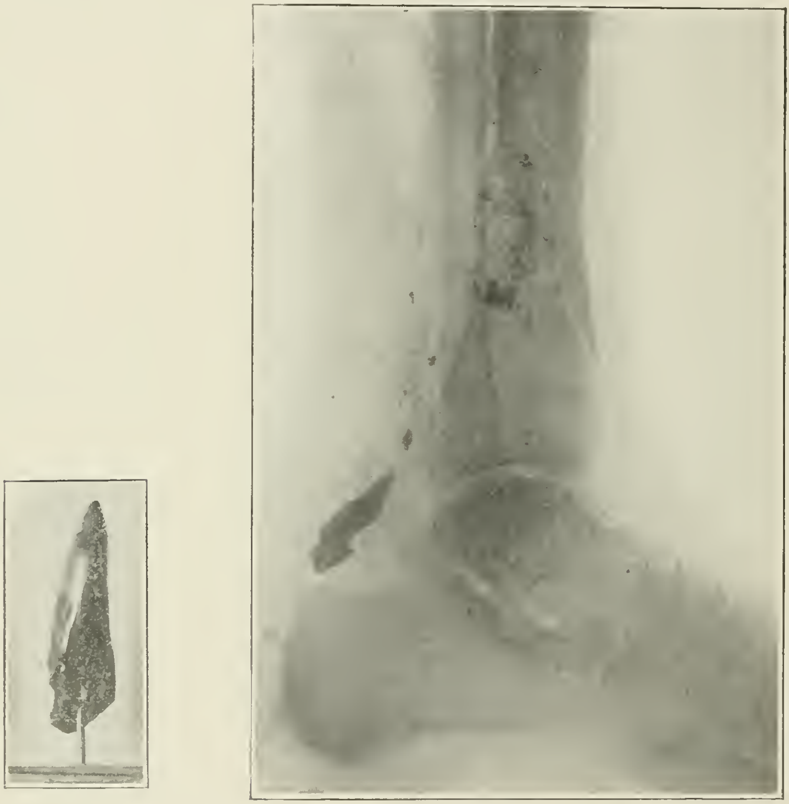


Fig. 39.—Skiagram showing oblique fracture tibia by ricochet Turkish pointed bullet. Lodged bullet was removed and shows to left of skiagram.

STOPPING POWER OF PROJECTILES FROM RIFLES, PISTOLS AND REVOLVERS

The stopping power of firearms is of vital importance on certain occasions. The sportsman after large vicious game feels more secure when he encounters an animal at close quarters if he is armed with a rifle that propels a missile with deadly effect. For personal encounters

FIG. 40.—Skiagram showing a partial butterfly fracture by Turkish bullet. Lodged bullet deformed.

FIG. 41.—Skiagram showing a lodged undeformed Turkish Spitz bullet under skin.

FIG. 42.—Skiagram showing a Turkish rifle bullet lodged in left knee-joint.

FIG. 43.—Skiagram showing a lodged Spitz bullet butt-end to.

Fig. 44.—Skiagram showing a lodged Turkish rifle bullet.

Fig. 45.—Skiagram showing Turkish rifle bullet lodged in right lung.

Fig. 46.—Skiagram showing lodged ricochet Turkish bullet from battle of Tamrach.

Fig. 47.—One and two are photographs of nucleus and envelope of lodged missiles in Fig. 46.

in self defense, it is useless to carry anything but an effective weapon. At war with savage tribes or a fanatical enemy, a military man seeks to arm his soldiers with a rifle that delivers projectiles with telling effect. A fanatic like a Moro wielding a bolo in each hand who advances with leaps and bounds and who never knows when he is hit until he is shot down must be hit with a projectile having a maximum amount of stopping power. Again, the military man has to reckon upon the stopping power of projectiles against cavalry and artillery horses in a charge.

The stopping power of the reduced caliber rifle bullet though less than that of its predecessors the .45-caliber Springfield, Martini-Henry, old Mauser, or Gras, is still considered sufficient for all the purposes of civilized warfare. At least it proved so in the Spanish-American, Boer, Russo-Japanese and the Turko-Balkan wars. Even the stoical Japanese soldier fell back as a rule when he was hit the first time. Five per cent. of the Japanese wounded were never admitted to hospital. They were treated on the line, but we are not told that they altogether ignored the fact of being wounded. We may assume that for all the purposes of war among civilized nations the present military rifle possesses sufficient stopping power. Major Charles Lynch, U. S. Army, our attaché with the Japanese Army in his report to the War Department, questions the stopping power of the Japanese bullet. This bullet is one of the lightest used by any of the nations, being 6.50 millimeters in caliber, 11 1/2 grams in weight. He states that "a man hit with the Japanese bullet will come on when it has passed through his body anywhere, except at a vital point." The stopping power of this bullet is not questioned by other observers but we are convinced of the truth of Major Lynch's statement when the weapon is used against a determined enemy or a savage tribe. Col. Stevenson states that the "medical officers who served in the Wizirestan Chitral Expeditions of 1895 where Lee-Metford rifles were first used in warfare, and Mr. H. C. Thompson who wrote the history of the latter campaign, believe that the English small-bore then in use could not be depended upon to stop a savage or determined man in a charge. "Many of the enemy in these two campaigns continued to advance and fight after the receipt of from one to six wounds by Lee-Metford bullets." These bullets were only effective upon striking vital parts or parts concerned in bodily activity. Our own officers have repeatedly reported in a similar way against the effectiveness of the Krag-Jorgensen bullet in the Philippine Campaigns.

Colonel Winter and Captain McAndrew, Medical Corps, U. S. A., have related the following incident to the author which bears upon the failure in stopping power of our service rifle: In 1907 a Moro charged the guard at Jolo, P. I. When he was within 100 yards, the entire guard opened fire on him. When he had reached within 5 yards of the firing party he stumbled and fell and while in the prone position a trumpeter killed him by shooting through the head with a .45-caliber Colt's revolver. There were ten wounds in his body from the service rifle. Three of the wounds were located in the chest, one in the abdomen and the remainder had taken effect in the extremities. There were no bones broken.

Sportsmen after large game in the Jungle prefer to arm themselves with the larger calibers. On account of the superior penetration and extended range of the jacketed bullets, the reduced calibers are only preferred in the open.

Because the stopping power of our .38-caliber Colt's revolver had failed us on numerous occasions in the Philippines and elsewhere the War Department constituted a Board in 1904 composed of Col. John T. Thompson, Ordnance Department and the writer, as the medical member, to conduct a series of tests with bullets of different size, weight and other characteristics, to determine upon a bullet that should have the stopping power and shock effect at short ranges, necessary for a pistol in the military service. To conduct these tests the Ordnance Department furnished the Board a number of pistols and revolvers with certain ammunitions as follows:

It will be seen by the table, pages 70 and 71, that the calibers varied between .476 inch, the greatest, and .3012 the smallest, which correspond to the extremes in variation in military pistols so far as was known to the Board.

Lead, jacketed and metal patch or soft-nose bullets were used. To produce dum-dum effects the points of some of the jacketed bullets were filed to expose the lead.

The form of bullets included the truncated cone, the spherical segment, blunt point, hole in point, cupped point, and one with a hole in point filled by a copper shell, primed and charged (explosive bullet.)

The weights of bullets varied between 92.6 grains and 288.1 grains.

The initial velocities varied between 700 f.s. and 1420 f.s.

The lowest muzzle energy was 191 foot-pounds and the highest was 415 foot-pounds. The revolvers and pistols were selected for their value in ballistic elements and not for a test of their mechanism.

Revolvers and pistols being short-range weapons, 75 yards were agreed upon as the extreme range, 37 1/2 yards as the medium range, and near the muzzle as close range. Simulated velocities were used for the first two ranges.

The Board fired altogether into ten cadavers, sixteen beeves and two horses. The shock on cadavers was estimated by the amount of

Fig. 48.—Antonio Caspi a prisoner on the Island of Samar, P. I. Attempted to escape Oct. 26, 1905. He was shot four times at close range in a hand-to-hand encounter by a .38 cal. Colt's revolver loaded with U. S. Army regulation ammunition. He was finally stunned by a blow on the forehead from the butt-end of a Springfield carbine. 1. Bullet entered chest near right nipple, passed upward, backward and outward, perforated lung and escaped through back passing through edge of right scapula. 2. Bullet entered chest near left nipple, passed upward, backward and inward, perforated lung and lodged in back in subcutaneous tissues. 3. Bullet entered chest near left shoulder, passed downward and backward, perforated lung and lodged in back. 4. Bullet entered palm of left hand and passed through subcutaneous tissues and escaped through wound on anterior surface of forearm. Treated at military hospital, Borongan, Samar. Turned over to civil authorities cured, Nov. 23, 1905. Reported by L. P. Lewald, 1st Lieut. Medical Corps, U. S. Army.

disturbance which appeared in a limb when the body was suspended by the neck.

We found that the amount of shock as measured by this method was always proportional to (1) the sectional area of the bullet, (2) to the resistance which the bullet encountered on impact, and (3) that it was proportional also to the amount of tissue destroyed. The diaphyses of the long bones showed the greatest amount of resistance, and consequently the greatest amount of destruction, and the two latter—viz., resistance and destruction of tissue, which are so

intimately associated with shock effects—were invariably greater when a larger caliber bullet was used.

In attempting to define shock effects or stopping power in living animals we had to consider shots against—

1. Vital parts.
2. Non-vital parts.
3. The anatomy necessary to locomotion or parts essential to activity.

(a) As one might suppose, all shots against vital parts from whatever arm showed immediate and complete stopping power.

(b) For shots in non-vital parts like the lungs, liver, intestines, etc., exclusive of large vessels the shock or stopping power increased with the sectional area of the missile and it was notably less with the smaller sectional area projectiles although they possessed far more energy.

(c) The stopping power of bullets upon colliding against parts necessary to locomotion or parts essential to activity was considered positive when fracture of the long bones occurred. Measured by this standard all the bullets tried possessed sufficient stopping power when for instance the tibia or femur was fractured. The stopping power of the larger caliber projectiles was considered positive in gunshot wounds of the epiphyseal ends of bones entering into the formation of the ankle, knee, hip, shoulder and elbow, and doubtful when these structures were traversed by the small .3012 caliber jacketed bullet of the Luger pistol.

In those cases where an effort was made to increase shock effects and destruction of tissue by the use of metal patch or marred jacketed bullets, these expedients failed in the soft parts and epiphyseal ends of bones, because the resistance in these tissues was not enough to disintegrate the projectile, or in any way to increase its sectional area.

As quick firing is an important element in close encounters, we made a number of tests to demonstrate what would be the stopping power by delivering the maximum energy of different projectiles in quick succession at close quarters, in bodily regions like the chest and abdomen away from the spine and large vessels. In this way we purposed to see how many shots it would require to cause an animal to drop to the ground. The animals selected were beeves about to undergo slaughter in the Chicago stock-yards. Each animal was tied to a post, and at the conclusion of each test, which occupied but a few seconds it was immediately killed in the usual way by the stock-yard

TABLE 3

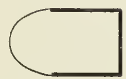
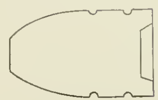
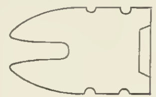
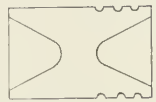
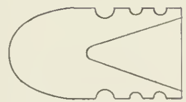
Make	Model	Caliber	Shots in magazine or cyl.	Powder charge: Weight gr.	Powder charge: Kind		Bullet: Weight gr.	Bullet: Kind	Bullet: Shape of point	Velocity f. s. at: Muzzle	Velocity f. s. at: 37 ½ yd.	Velocity f. s. at: 75 yd.	Energy ft.-lb.: Muzzle
1. Luger Automatic Pistol.	Medium barrel	3012	8	6.2	Smokeless		92.6	Jacketed	Truncated cone	1420	1258	1133	415
2. Luger Automatic Pistol.	Short barrel	3543	8	5.2	Smokeless		123.5	Jacketed	Truncated cone	1048	985	930	301
3. Colt's Revolver...	Army, 1903	38	6	3.3	Bull's eye		148.0	Lead	Sph. seg.	763	727	690	191
4. Colt's Automatic Pistol.	Military 1902	38	8	6.6	Smokeless		130.0	Jacketed	Sph. seg.	1107	1022	953	354
5. Colt's Automatic Pistol.	Military 1902	38	8	6.5	Smokeless		120.0	Soft nose	Sph. seg.	1048	980	920	293
6. Colt's Revolver...	New Service	45	6	4.8	Bull's eye		250.0	Lead	Blunt point	720	692	668	288

TABLE 3—(*Continued*)

Make	Model	Caliber	Shots in magazine or cyl.	Powder charge			Bullet			Velocity f. s. at			Energy ft.-lb.
				Weight gr.	Kind		Weight gr.	Kind	Shape of point	Muz-zle	37 ½ yd	75 yd.	Muzzle
7. Colt's Revolver...	New Service	45	6	4.8	Bull's eye		220.0	Lead	Hole in point	700	691	683	239
8. Colt's Revolver...	New Service	455	6	6.4	Cordite		218.5	Soft lead	Cupped	801	704	616	288
9. Colt's Revolver...	New Service	476	6	18.0	Black		288.1	Lead	Sph. seg.	729	686	646	340
10. Colt's Revolver..	New Service	476	6	18.0	Black		288.1	Lead, explosive	Sph. seg.	729	686	646	340

force. For the purpose of the quick-firing experiments we employed the following calibers: .47.6, 45.5 and .45 from Colt's revolvers; the .38-cal. Colt's automatic and the .3012 Luger pistol which employed the steel-clad bullets. All of the bullets used in the experiments lodged in the body so that every particle of energy was delivered with each bullet. The animals invariably dropped to the ground when shot from three to five times with the larger caliber Colt's revolver bullets, and they failed in every instance to drop when as many as ten shots of the smaller jacketed bullets from the Colt's automatic and Luger pistol bullets had been delivered against the lungs or abdomen. This failure on the part of the automatic pistols of small caliber set at rest at once the claims of the makers to the effect that the superior energy and velocity of their weapons was a controlling factor in stopping power. The Board was of the opinion that a bullet which will have the shock effect and stopping power at short ranges necessary for a military pistol or revolver should have a caliber not less than .45. The tests showed that the .47.6-caliber lead bullet has the greatest stopping power. Its weight is 288.1 grains, muzzle velocity 729 f.s.; muzzle energy 340 foot-pounds. The .45-caliber lead bullet slightly blunt point was next in stopping power. It weighs 250 grains with a muzzle velocity of 720 f.s. and muzzle energy of 288 foot-pounds. A slightly blunt point has the advantage of making a bullet bite better in striking a hard bone at an angle, or in clipping the edge of a vessel. All things considered such a bullet is best suited for the military service in close combat. The Board considered that cup-pointed bullets such as the "man stopper" might be issued to troops fighting savage tribes, and fanatics in the brush or jungle. This bullet showed great execution on live animals. It weighs 218.5 grains. It has a muzzle velocity of 801 f.s. and a muzzle energy of 288 foot-pounds. The edge of the cup readily mushrooms upon striking cartilage and joint ends of bones, thereby adding to the sectional area and stopping power.

None of the full-jacketed or metal-patch bullets (all of which were less than cal. .45) showed the necessary shock effect or stopping power for a service weapon. They failed especially in the joint ends of bones and non-vital parts which comprise the larger part of the target area presented by the human or animal body. In the event that an automatic pistol should eventually be adopted by the government it was recommended that the caliber should not be less than .45, and that the point of the jacket should be made very thin and that the lead core be made of softer lead than that of any of the bullets tested. The

object of this was to invite mushrooming. We were well aware that this recommendation would not be adopted because the comity of nations frowns upon any device which is calculated to increase the severity of wounds in war. The United States Government has recently adopted the .45 caliber Colt's automatic pistol which uses the steel-clad bullet without features to invite deformation.

Fig. 49.—Fracture of femur by Colt's new service revolver .476 cal. at simulated velocity of 75 yards. Army Medical School collection.

Fig. 50.—Perforation head humerus with slight fracture by Colt's new service revolver cal. .476 at range of 37 1/2 yards. Army Medical School collection.

Shock effects depend upon the sectional area of a bullet and the amount of energy which it delivers at the point of impact. A full-jacketed bullet which makes a clean fracture in bone, and then leaves the body, takes the greater part of its energy in flight. When the bone is very resistant or the jacket is marred, the bullet may disintegrate. Its sectional area is then increased, and it leaves its energy in the body in proportion to the amount of metal which it deposits in the foyer of fracture. When it lodges entirely, it parts with all of its remaining energy. In comparing skiagrams showing fracture one can estimate wholly or in part the amount of the remaining energy or shock effects

in a given case by the amount of metal which is deposited. By this standard one will see at a glance the striking difference which is nearly always shown between a bone lesion by a full-jacketed bullet, one that is but partially jacketed, and one that is unjacketed as in the case of a lead bullet. Full-jacketed projectiles leave but few metallic particles about the area of fracture as a rule. A partially jacketed bullet, like a metal-patch, or a bullet with nose marred purposely or otherwise, will leave numerous fragments, some of them much darker

Fig. 51.—Fracture of humerus by Colt's new service revolver .45 cal. Bullet with blunt point, close range. Army Medical School collection.

Fig. 52.—Fracture of femur Colt's new service revolver .45 cal. carrying a bullet with hole in point close range. Army Medical School collection.

than others. Those that are darker or black represent part of the lead core, while the fragments of lighter shade represent part of the envelope. The presence of dark fragments alone indicates the result of a lesion by an ordinary unjacketed lead bullet or a shrapnel ball, and more often the latter if the case is one from the very recent wars in which shrapnel balls are so frequently used.

The following skiagrams exhibit bone lesions in cadavers when fired into with projectiles from pistols and revolvers (see Table No. 3).

Fig. 53.—Man-stopper bullets from Colt's new service revolver cal. 455 lodged against tibia and femur without fracture. Remaining velocity at 75 yards. Army Medical School collection.

The X-ray work was done by Professor A. Hewson and Doctor W. M. Sweet, of Philadelphia (Figs. 49 to 68).

We are not acquainted with any bullet fired from a hand weapon that will stop a determined enemy when the projectile traverses soft parts alone. The requirements of such a bullet would need to have a sectional area like that of a 3-inch solid shot the recoil from which when used in hand weapons would be prohibitive.

Finally the Board reached the conclusion that the only safeguard at close encounters is a well-directed rapid fire from nothing less than a

Fig. 54.—Fracture of tibia from man-stopper bullet fired from Colt's revolver new service cal. .455, velocity 704 f.s. Bullet fragmented and lodged just under skin. Army Medical School collection.

.45-caliber weapon. With this end in view soldiers should be drilled to fire at moving targets until they have attained proficiency as marksmen.

The pointed bullet recently adopted for the military rifle by the United States, Germany, and England, will no doubt exhibit greater stopping power than its predecessors which, as we have already shown, has hitherto failed entirely in encounters with savage tribes.

Fig. 55.—Fracture of femur by Colt's new service revolver, carrying man-stopper bullet, caliber .455 with simulated velocity at 37 1/2 yards. Note butterfly character of fracture. Army Medical School collection.

Fig. 56.—Perforation by marred bullet from Colt's automatic pistol .38 cal. The jacket was not ruptured on impact. Range 5 yards velocity 1107 f.s. Army Medical School collection.

FIG. 57.—Perforation neck femur by soft nose or metal patch bullet from Colt's automatic pistol .38 cal. at 5 yards. Army Medical School collection.

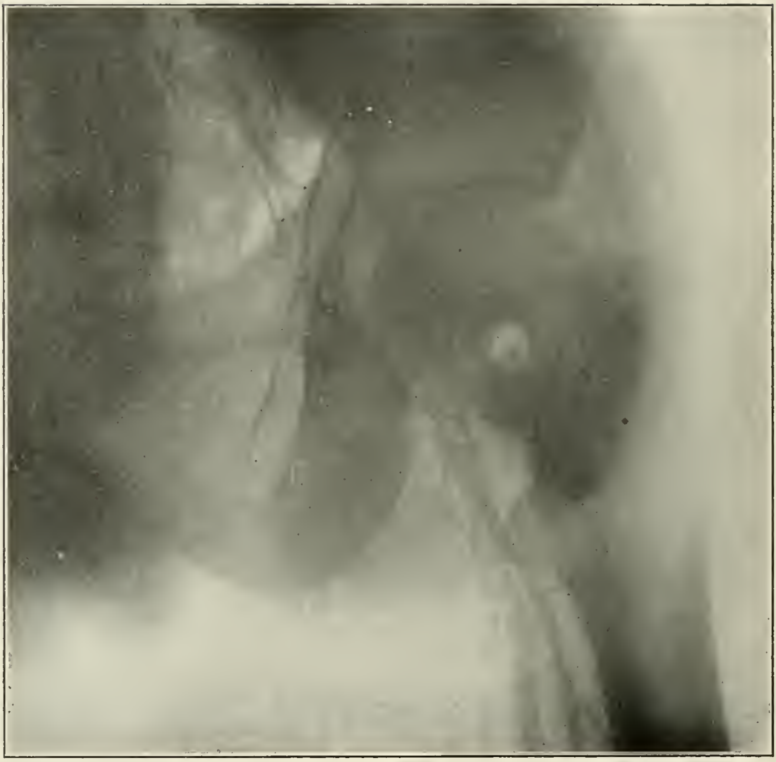


Fig. 58.—Perforation head femur by the 9 mm. Luger pistol-jacketed bullet remaining velocity at 37 1/2 yards. Army Medical School collection.

Fig. 59.

Fig. 60.

Fig. 59.—Fracture of tibia by Colt's automatic pistol .38 cal., full-jacketed bullet, remaining velocity at 37 1/2 yards. Metallic fragments are few in number and very small. Army Medical School collection.

Fig. 60.—Fracture by Colt's automatic pistol .38 cal., full-jacketed bullet close range. Army Medical School collection.

Fig. 61.—Fracture from soft nose bullet, Colt's automatic pistol .38 cal. at 5 yards. Army Medical School collection.

Fig. 62.—Fracture from soft nose bullet, Colt's automatic pistol .38 cal. at 5 yards. Army Medical School collection.

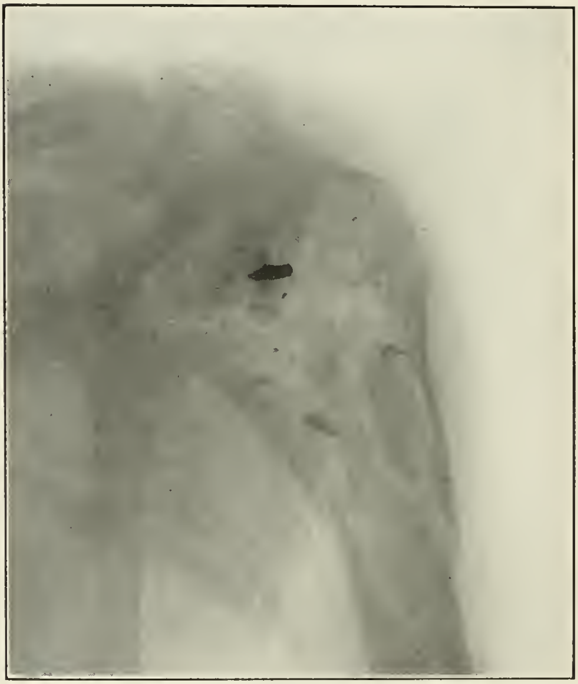


Fig. 63.—Fracture of so-called man-stopper bullet from Colt's .455 caliber new service revolver at 5 yards. Army Medical School collection.

FIG. 64.—Butterfly fracture by Colt's automatic pistol bullet .38 cal., at close range. Jacket of bullet was marred by filing the point of projectile.

FIG. 65.—Fracture from Colt's new service revolver unjacketed bullet .38 cal. at 25 yards. Army Medical School collection.

Fig. 66.—Fracture with butterfly arrangement of fragments from Colt's new service revolver, unjacketed bullet, at 74 yards. Army Medical School collection.

Fig. 67.—Fracture from Colt's new service revolver, unjacketed bullet, .38 cal. at 5 yards. Army Medical School collection.

Fig. 68.—Fracture by soft nose bullet, Colt's automatic pistol Cal. .38 at 5 yards. Note lodgement of lead nucleus, fragmented. Army Medical School collection.

Explosive effects in gunshot wounds at proximal ranges by the high-power rifles were referred to in the beginning of this Chapter, p. 36. They were noted by all experimenters upon cadavers and animals, and there is record of their appearance in war, especially in the Manchurian campaign. Generally speaking, these highly destructive effects are commonly seen when using the older rifles like the .45-caliber Springfield and the Martini-Henry of the English Army up to 350 yards, and with the rifles of reduced caliber the characteristic effects have been noted still farther.

The term "Explosive Effects" is in a measure confusing because it conveys the impression that the wound is the result of an explosion, or explosive bullet. The term is entirely descriptive and it owes its origin to the similarity in the appearance of a wound caused by an explosive ball *per se*, as compared to a bullet having sufficient velocity and energy to show a corresponding lesion, when a proper impact is made, as for instance, against resistant bone. As a rule the entrance wound presents no special features. In a few instances it may contain bony sand. When a resistant bone has been hit the area of fracture shows loss of substance, the bone will have been finely comminuted, the pulvarized bone will appear not only in the line of flight of the bullet but in all directions, viz., at right angles to the channel and backward into the wound of entrance. Pulpification of the tissues will be noted along the parts adjacent to the channel made by the bullet and for some distance beyond. The exit wound is large and lacerated with the appearance of an explosion having occurred from within. Torn muscles, tendons, and at times lacerated nerves, mingled with pieces of bone, protrude from the injured parts. The channel from the wound of exit is funnel-shaped with the base of the funnel corresponding to the exit wound and the apex at the seat of fracture.

Bony structures are not alone in showing these marked lesions with high velocities. Some observers have noted explosive effects up to 500 yards with the reduced caliber bullet in "very vascular tissues, cavities filled with liquid, semi-liquid or viscous masses, such as the heart, skull, stomach, intestines, etc. Fig. 104 shows the effects of a proximal shot on the skull of a soldier who was endeavoring to escape from the guard at Fort Sheridan. The lesion is typical of explosive effects so-called and in our experience it does not differ from proximal shots on cadavers. For other evidences of explosive effects on the head see Figs. 101, 102 and 105.

We had never seen a wound caused by an explosive bullet, and in order to compare the lesion in such a wound with the explosive effects of bullets we fired into a horse's thigh while experimenting for the stopping power of bullets at Chicago. The bone lesion observed was not different in our experience from the lesion frequently described under the term explosive effects.

All writers on the subject have sought to explain the so-called explosive effects, but it remained for Col. Stevenson in his book "Wounds in War," to give us a comprehensive description of the theoretical and true explanation of these interesting lesions. He takes up the subject under the following headings:

1. The theory of compressed air.
2. The theory of hydraulic pressure.
3. The theory of rotation of the bullet.
4. The theory of deformation of the bullet.
5. The theory of heating of the bullet.

At the onset we may state that none of the theories referred to comes up for serious consideration. They are merely mentioned to explain the confusion that once obtained in interpreting the mechanics of projectiles.

1. **Theory of Compressed Air.**—This is among the oldest of the theories to explain explosive effects. The advocates of this theory believed that the projectile massed a cushion of compressed air on its head, and that on impact this compressed air again expanded, with more or less violence, not unlike the expansive force of an explosive, thereby causing the appearances of internal pressure which are noted in wounds showing explosive effects. There is no evidence of air having been forced into the tissues and we know also that air is extremely mobile and that it can only be compressed when imprisoned under great pressure.

2. **Hydraulic Pressure.**—This theory came into prominence because water when fired into, offers great resistance to the passage of a bullet. The act of firing into cans of water that are sealed or unsealed exhibits the effects of a powerful internal pressure. The hydraulic theory can only be employed to explain destructive effects in tissues where an organ like the stomach, or urinary bladder is filled with fluid at the moment of impact. In such a case the explosive effects simulate those seen in the case of a femur as far as lacerations and contusions are concerned. In reckoning upon the subject of explosive effects one must always bear in mind that explosive effects are proportional

to (1) the velocity, (2) sectional area, (3) deformation and (4) to the resistance, on impact. Concerning the latter we may add that there are two things in the human body that offer a maximum of resistance, viz., compact bone and water. In order to exhibit its maximum resistance the water has to be in the form of a fluid or a semi-fluid mass contained in a cavity.

The velocity of rotation as a cause of explosive effects needs but a passing notice. As we have already shown, the velocity of rotation

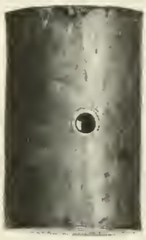


Fig. 69.

Fig. 70.

Fig. 71.

Fig. 72.

Fig. 73.

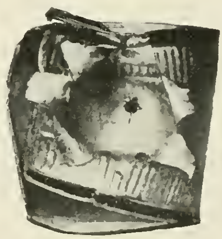


Fig. 74.

Fig. 69.—Shows orifice of entrance in an empty tin at 10 ft. by the Karg-Jorgensen bullet.

Fig. 70.—Shows orifice of exit in same vessel.

Fig. 71.—Shows orifice of entrance in a tin filled with marbles.

Fig. 72.—Shows orifice of exit in the same vessel. Note the impression of marbles on sides of tin caused by lateral pressure.

Fig. 73.—Orifice of entrance in a tin sealed and filled with water.

Fig. 74.—Orifice of exit in the same vessel.

of the reduced caliber bullet with ogival head makes 2400 turns per second at the muzzle, and the pointed bullet adopted by our army and that of Germany and England on account of added velocity makes 3240 turns. The velocity of rotation does not diminish as rapidly as the velocity of translation, that is, it is better maintained even to the latter end of the projectory. The rotation of the small bullet is given to it by a shorter twist in the rifling, or one complete turn in 10

inches. If a bullet makes a turn on its long axis in 10 inches of its flight when traversing the femur for instance—the latter being about 1 inch in diameter—the amount of turning which it would do while fracturing the femur would about equal one-tenth of a turn, and it is not likely that this amount of rotation could in any way be responsible for the enormous effects noted in such cases.

As to the theory of heating to explain explosive effects, our experiments quoted elsewhere have demonstrated conclusively that a projectile does not become sufficiently heated by the act of firing to destroy microorganisms placed upon it. This being the case, the theory is, to say the least, not tenable.

While we were experimenting with the new bullet some years ago we repeated many of the experiments of von Coler and others to show so-called explosive effects by firing into empty tins, tins filled with water, sealed and unsealed; tins filled with wet and dry sawdust, also tins filled with starch-paste and marbles. (See Figs. 69 to 74.)

The True Cause of Explosive Effects.—If we bear in mind the factors necessary to produce explosive effects—namely, velocity, sectional area, deformation, and resistance on impact—we have to recall the fact that all these factors have abided with us, except the high velocities, since the early history of firearms. The latter appeared with the perfection of the military rifle. Of the factors mentioned, which relate to the projectile, velocity is the most potent and next in order come sectional area and deformation. The velocity of the old Springfield rifle bullet was 1300 f.s. and that of our present rifle bullet is 2700 f.s. The energy of the Springfield bullet was 1879 foot-pounds while the energy of the U. S. magazine rifle (now called the New Springfield rifle) bullet is 2400 foot-pounds. Although the velocity has been doubled we find that the energy has not been increased correspondingly. This is due to the diminution of the sectional area and weight of the smaller bullet. The weight of the bullet was reduced in the change mentioned from 500 to 152 grains, while the velocity was doubled. The 152 grains jacketed bullet impressed with a remaining velocity of 1300 f.s., which was the maximum velocity of the Springfield's 500-grain bullet, shows no explosive effects. If it travels at its maximum speed 2700 f.s. or thereabouts, it causes enormous destructive effects so that we must attribute its power to destroy tissues to its superior velocity. When the two guns mentioned are shot side by side, at similar ranges, into parts offering the same resistance, it is found that the explosive effects of the two bullets are the same for the proxi-

mal ranges up to about 350 yards, and they continue to be equally severe with the smaller bullet up to 500 yards. On the skull of cadavers with brain and scalp *in situ* we have noted all the appearances of explosive effects as far as 900 yards.

If one will examine the foyer of fracture and the funnel-shaped channel leading to the wound of exit as a result of a gunshot injury by the heavier lead bullet at proximal ranges, he will find pieces of the disintegrated lead from the bullet, and bone particles, dispersed in all directions as already explained. It is most evident from a study of the force which caused these particles to penetrate the tissues, that they were made to act as secondary projectiles by some of the energy of the bullet, which was transferred to them at the moment of impact. In cavities containing fluid contents, the fluids are dispersed and part of the energy of the bullet is transferred to particles of water or fluid masses, and they in turn are propelled from their original positions to act as secondary projectiles. The true cause of explosive effects may be said then to be the transfer of energy from the bullet to particles of its own composition when it disintegrates, as well as to spiculæ of bone, or particles of fluid, or soft tissues. The amount of destruction is measured by the degree of energy inherent in the bullet, and we should add that the latter depends upon the velocity which the projectile possesses at the time of impact. Sectional area and deformation of the projectile favor destruction of tissue, but they are not essential, since small jacketed bullets that show no deformation upon colliding with resistant bone at close range exhibit explosive effects bearing close similarity to those instances when the envelopes and core of the bullet undergo fragmentation.

WOUNDS BY PROJECTILES FROM THE ARTILLERY ARM

These will include wounds by shells, shell-fragments and shrapnel.

Shell Wounds.—Injuries from shells are more often inflicted by fragments of shells after bursting. They vary in accordance with the size and irregularity of the fragment. They are always lacerated and contused. Wounds of the limbs especially, bear great similarity to those seen in civil practice, from machinery or railroad accidents. Lodgment of missiles is often noted because the velocity of the pieces of an exploded shell is low. When a whole shell hits at a high rate of velocity, it carries everything before it. When striking the body

of an individual, a large opening will be made corresponding to the size of the projectiles, and viscera adjoining the point of impact are dislodged and scattered. Longmore states that in the case of a limb which has been carried away by a shell or solid shot "the end which remains attached to the body presents a stump with a nearly level surface of darkly contused, ragged, but still connected tissues, deeply imbued with blood. The flesh presents an aspect of having been torn asunder, by a sudden irresistible force. The skin and muscles do not retract, as they would do, had they been divided by incision. Particles of bone will be found among the soft tissues on one side of the wound, but the portion of the shaft of the bone remaining *in situ* will probably be found unsplintered and without long projecting jags or points." When the velocity of the large projectile is low, the injury is quite similar, only it is attended with more laceration and a ragged condition of the skin. The surface of the wound is not so even. The bone of a limb exhibits larger spiculæ with greater tendency to fissuring in the part of the bone remaining. There is more extravasated blood, and contusion of the soft parts is more apparent. In the case of a spent shell or shot there may or may not be external evidence of injury, but there will be evidence of extensive disorganization in the way of contusion, laceration, crushing of soft parts, with or without bone lesion.

In the Civil War out of 245,790 gunshot wounds 359 were reported due to solid shot, and 12, 520 to shell fragments. Since shells are now used to the exclusion of solid shot, wounds from the latter are no longer seen in modern wars. Shells are more especially used against material and wounds from this projectile or its fragments will not occur very frequently, except in siege operations and in naval combats. Shell wounds in the Spanish-American war aggregated 7 1/2 per cent. of all wounds, but these were mostly from shrapnel balls. Although there are no definite figures yet available for this class of wounds in the South African War, it is safe to predict that the latter figure will hardly be exceeded. Makins reports that shell wounds from shell fragments formed but a small proportion of the injuries treated in hospitals in the latter war. His reference to this class of wounds is not hopeful. He states that "the features presented were those of lacerated wounds, while the more severe of the cases which survived only offered scope for operations of the mutilating class, so uncongenial to modern surgical instincts." Makins also states that in some cases the impact was made by the flat surface of a fragment from which there

was no visible sign of injury. In one case of this kind the blow was delivered upon the epigastrium of a soldier and it was followed by vomiting of a considerable quantity of blood.

Wind Contusion.—The case just referred to by Makins would have been called a *wind contusion* by the older writers on gunshot wounds. When solid shot and shell were more often employed in battle, surgeons often saw cases of extensive internal injury to the viscera, disorganization of soft parts, and even fracture of bone with no visible evidence of injury to the surface. Such cases were attributed to the rapid displacement of the air in the vicinity of the injured, and the subsequent shock from refilling of the vacuum thus caused. But intelligent men like Longmore and Baron Larrey soon learned that the lesion in so-called *wind contusion* was the result of pressure of heavy projectiles having slow momentum, against a tough elastic skin. In such cases Longmore believes that the blow is delivered obliquely and that as the elastic skin yields, the more resistant structures beneath are crushed and disorganized. There is nothing in our knowledge in the way of air displacement that will cause lesions marked by the disorganization mentioned except the sudden liberation of the gases of the high explosives, and in these cases there is always tearing of the skin with other traumata.

The statistics of injuries by shells and shell fragments in the Manchurian campaign, like those in the Spanish-Amerian war, are not reliable for the reason that "in the field nearly all wounds classified as Shell Wounds were caused by Shrapnel" (Lynch). Follenfant[1] states that wounds by shells charged with chimose powder were very different to those made by Shrapnell. The envelope of these chimosed shells was reduced to small particles, like scales, or cubical in shape, with sharp sides and angles which were apt to tattoo the wounded like so many grains of salt. The mental shock caused by the explosion and the resulting wounds brought on nervous symptoms, especially in officers, like neurasthenia or traumatic hysteria. These nervous symptoms were also attributed by some observers to poisoning from the gas of explosion, which was absorbed from the small fragments, lodged in the cellular tissues.

For a complete description of the effects of large projectiles in modern war we have to turn to the labors of our naval confréres. Surgeon General Charles F. Stokes, U. S. Navy[2], calls attention to the

[1] Archives de Medicine et de Parmacie Militaries No. 48, 1906. By M. Follenfant, French Army.

[2] Proceedings of New York State Medical Society for 1912.

probable casualties and deadly results in future wars between modern battleships. The new 14-inch guns on board have an effective range of 14 miles and they can fire with accuracy on moving targets at 7 to 9 miles with amazing rapidity. Each of the guns fires a projectile weighing 1400 pounds at a velocity of 2900 f.s. The powder charge of a 14-inch piece weighs 350–400 pounds and in addition it carries a bursting charge that invites extensive fragmentation of the projectile on impact. Both the propelling and bursting charges are largely composed of the modern high explosives which yield poisonous gases like CO, and NO_2, as products of combustion. Indeed one of the chief menaces in naval warfare to-day will be poisoning from powder gases arising from the bursting shells of the enemy and the batteries on board each ship. As pointed out by General Stokes there will be two types of poisoning —"one resembling illuminating gas poisoning, the other irritative in its effects. Both may vary in degree. In the one group, in mild cases, we find dilatation of the pupil, impaired vision, a fall in blood pressure, a rapid heart action and possibly some mental confusion." Slighter degrees of poisoning will doubtless impair the effectiveness of the men, and larger dosage will cause them to succumb into unconsciousness and death. The best account in our literature on the effects of modern naval armament in recent wars is found in the Japanese Government Report by Saneyoshi and Suzuki[1] on the casualties of the naval combats in the Chino-Japanese War in 1894–95. Aboard ship the character of wounds from shells and shell fragments hitting the vicinity of the men differs materially from that seen in battle on land. On board ship injuries arise from splinters of planks and furniture, pieces of iron, etc., which are mobilized by bursting shells, and act as secondary projectiles. A shell exploding a magazine causes many injuries by burning and the fumes of powder gases in confined places are very irritating to the mucosæ. The rending effects of the sudden displacement of air by detonating explosions is mentioned as an additional agent in causing injury.

The injuries on board ship are divided as follows: (1) contusions, (2) abrasions, (3) penetrating, (4) perforating, (5) lacerating, (6) mutilating, and (7) burn.

(1) **Contusions.**—The proportion of simple contusions are relatively small because of the limited range, and on account of the irregularity

[1] The Surgical and Medical History of the Naval War between Japan and China, 1894–95, by Baron Saneyoshi and Doctor Suzuki, Japanese Navy.

of the surface of the projectiles, which invite direct injury to the skin with resulting abrasion, laceration, etc.

(2) Abrasions are for the above reasons more frequently noted, and they are often incurred by fragments striking obliquely.

(3) **Penetrating Wounds.**—These wounds are inflicted by missiles possessed with low velocity and they find lodgment in the majority of cases. The penetrating wound shows but one wound—that of entrance.

(4) **Perforating Wounds.**—These wounds are marked by a wound of entrance and one of exit. They are usually caused by small pieces of shell about the size of a .38 caliber projectile and more or less regular in outline. The wound of entrance conforms to the shape of the projectile with lacerated edges, showing contusion of the adjoining tissues. Except in cases where the skin is stretched over bone or tendon, the wound of entrance is smaller than the wound of exit. The wound of exit is larger at times when the fragment leaves the body with its largest diameter at right angles to its line of flight. As a rule the resistance of the tissues causes the fragment to turn, so that its longest diameter remains coincident with the direction in which it is moving, making a smaller exit wound thereby.

(5) **Lacerated Wounds.**—These wounds are usually inflicted by a shell or a large fragment. They are marked by section of the body in two parts, the severance of the head, hand or leg from the body. Forms of injury are also noted where continuity of the body still persists, as after extensive laceration of the chest or abdomen.

(6) **Mutilated Wounds.**—This term is used to describe the wound in cases where the body or anatomical part is mutilated beyond recognition of its human form. Those sustaining the mutilation of a limb survive but a short time as a rule; they usually succumb to shock rapidly.

(7) **Burn.**—This is by far the most frequent injury seen in naval combat. It comes directly from the explosion of shells and the ignition of ammunition in the vicinity of the explosion, and it sometimes arises from steam, which is liberated from containers that are perforated by projectiles. On the "Matsushima" a 30-cm. shell struck a gun-shield, and as it exploded it set fire to some ammunition near by. One hundred sailors were killed and wounded. Twenty-five had the body destroyed entirely; one suffered mutilation of all four members; four were entirely burned. Of the seventy wounded twenty-two succumbed to burns in from twenty-four hours to a period of six weeks.

In the more serious cases, the face was blackened, the hair singed, the head was covered with black-yellowish scabs, the eyes were closed, the nostrils were obstructed and the ears were tumefied, the mouth was opened with difficulty.

Saneyoshi and Suzuki note that traumatic delirium is the most frequent complication of burn aboard ship and that of all injuries in naval combat burn is the most painful.

Rupture of Membrana Tympani.—This complication is often noted as a result of reverberations from the firing of cannons and the explosion of shells. Rapid displacement of air in the vicinity of detonating ammunition is offered as an additional cause.

Primary Hemorrhage.—This symptom is rarely seen in shell wounds for reasons already referred to. But two deaths were reported in the Chino-Japanese war, one from a shell injury of the larger vessels of the abdomen, and the other from a piece of shell which cut through the neck from side to side severing the trachea, esophagus, and right carotid. Secondary hemorrhage is practically absent, presumably on account of the use of modern methods in wound treatment.

Shock is not so dependent upon the location or character of the wound as it is to the mental state of the individual at the time of injury. Saneyoshi and Suzuki cite cases of shock in wounds of the head, chest and abdomen, as well as in cases of mutilated injuries of the limbs; and again cases of men are cited who labored under great mental excitement when hit and who though fatally wounded, with perforation of the abdomen, mutilated limbs, etc., showed no symptoms of shock whatsoever up to the time of death. Per contra, persons were seen to go into a state of shock which seemed to bring on paralysis of the nervous system from proximity to a bursting shell alone. Burn was responsible for many of the cases of shock.

Traumatic delirium as a symptom is noted in those wounded who were in proximity to the explosion of large shells. Burn, nerve exhaustion from pain, and loss of sleep are mentioned as contributing causes of traumatic delirium. Out of a total of 629 injuries received from various causes in the above-named war 50.2 per cent. were due to shells and shell fragments as follows:

Contusions	19 cases in	14 persons.
Abraded wounds	47 cases in	30 persons.
Gutter wounds	6 cases in	6 persons.
Wounds attened with loss of soft tissues	4 cases in	4 persons.

Contused wounds	97 cases in	59 persons.
Penetrating wounds	57 cases in	41 persons.
Perforated wounds	33 cases in	30 persons.

Lacerated and mutilated wounds occurred as follows:

Hit by entire shell	10 cases.
Hit by fragment shell	27 cases.
Hit by iron pieces	5 cases.
In the neighborhood of shell explosions, causative effects uncertain	8 cases.
Uncertain whether hit by shell fragment or iron pieces	2 cases.
By compression	1 case.
Total	53 cases.

For excellent colored plates showing wounds by shell fragments, burn and other lesions which occurred in the Japan and China War, 1894–95, see the Surgical and Medical History of the Naval War by Baron Saneyoshi and S. Suzuki, Tokio.

Dr. Matthiolius[1] also reports upon the gravity of modern naval war wounds from the battle of Chemulpo, the first engagement in the Russo-Japanese War. The Russian Cruiser "Varyag" was put out of commission in fifty minutes with a casualty list of 41 killed and 64 wounded, being 18 per cent. of her effectiveness. On account of the large penetrating steel shells, men were completely mutilated, amputations were immediately necessary in a number of cases. One of the sailors received 160 wounds from the explosion of one shell. In the same war Dr. Totsuka[2] in a total of 2321 casualties in naval engagements, from all causes, before Port Arthur from February 9, to October 1, 1904, gives a mortality of 1022; 88 died from unknown causes, 556 of the wounds were severe and 655 were classed as slightly wounded. The exact number of casualties which may be attributed to shells or their fragments is not given. He states that the shell wounds were generally multiple. In 36 wounded there were 62 wounds, not counting excoriations and slight wounds. Some wounds were the size of a pea, others large enough to mutilate a limb. The wounds consisted of abrasions, contusions, blind wounds, perforating wounds, the last of these being less often seen, owing to the low velocity of fragments Small wounds healed rapidly, but the large wounds all suppurated.

[1] "Les blessures dans la guerre Russo-Japonaise. Dr. Matthiolius, Marine Imperiale allemande Le Caducée, p. 11, 1904."

[2] Report of the Wounded admitted to the Sasebo Naval Hospital by K. Totsuka, Surgeon General I. J. Navy, Sei-i-kwai Med. Jour., May 31, 1904.

Pom-pom Shell.—Wounds from this projectile or its fragments. do not differ from injuries inflicted by the larger shell. The shell is fired from the Maxim automatic gun at intervals of a few seconds. It was first used in the Boer War. Makins states that the effect was principally a moral one, due to continuous firing of the gun and the unpleasant noise which it made. The shell failed to explode at times and as it was sufficiently small, the whole projectile was known to perforate the body in a number of cases.

Wounds by Projectiles from Case Shot, Canister and Shrapnel.—The former of these have been altogether superseded by the use of shrapnel. Since their projectiles are similar in caliber, shape and weight, and generally speaking in composition to the shrapnel bullet, and as the balls of all these projectiles are possessed with low velocity on impact, the wounds they inflict are very similar, and they correspond to the description of wounds by shrapnel balls. Again, shrapnel wounds differ in no respect from wounds produced by spherical balls from low-velocity weapons of other days. The canister and shrapnel balls have generally been spherical in shape and of an average of .50 calibers in diameter. Whether they are liberated by the shock of impact or a time fuse the velocity is low, the tendency is for the missiles to lodge, the wounds are often multiple, and they nearly always suppurate. There were but 1153 gunshot wounds from grape[1] and canister reported in our Civil War of 1861–65 out of a total of 245,790 wounds from all kinds of projectiles. Since the modern shrapnel forms about 80 per cent. of the artillery ammunition on the field of battle we will expect more casualties from this source in the future. In recent wars the proportion of shell and shrapnel wounds taken together is very much increased in number. In the Manchurian campaign Lynch[2] states that for the first Japanese Army the military rifle wounds were 84 per cent., shell 14 per cent., and bayonet 0.9 per cent. This army was engaged in field operations alone. In the third army which had only siege operations at Port Arthur and but one battle, Mukden, the rifle wounds were 59 per cent., cannon 19.63 per cent., bayonet 0.59 per cent. The percentages for the three armies taken together is: rifle 76.42, cannon 15.78, bayonet 0.63. The remaining percentages figure among the miscellaneous and untraceable.

[1] The grape shot of the Civil War was made of about 9 spherical iron balls held together by rings and cast-iron plates. They separated by the shock of discharge from the cannon.

[2] Reports of Military observers, etc., Part IV. Report by Major Charles Lynch, U. S. Army, 1907.

Fig. 75.

Fig. 76.

Figs. 75 and 76.—Shrapnel balls, pieces of casing and other missiles removed from wounded soldiers in the Russo-Japanese War. From the U. S. Army War College collection.

In the field all wounds classified as shell wounds were practically due to shrapnel.

There were but few cases of shrapnel wounds reported in the Spanish-American War. In the South African War, the Boers were poorly provided with artillery. They used shrapnel with little effectiveness owing to bad marksmanship. The shrapnel wounds noted were from leaden shrapnel bullets mostly from British shells. "The wounds possessed little special interest except from the fact that the bullets were often retained" (Makin). The same author saw one patient who had suffered six penetrating wounds from the bursting of one shrapnel. Although the body wounds from shrapnel balls are considered uniformly dangerous to life, Makin mentions one case of remarkable recovery as follows: "A Boer wounded at Graspan.

Fig. 77.—From Turko-Balkan War 1912–13. Bulgarian artilleryman wounded by a bursting shrapnel at Lule Burgas.

Aperture of entry (shrapnel) opposite eighth left costal cartilage, 1 inch external to nipple line. The opening was circular and surrounded by an area of ecchymosis 4 inches in diameter; exit 4 1/2 inches above and to the right of the umbilicus. Patient was at first in a Boer ambulance, and only seen by me on the ninth day. At that date he was dressed and walking with a gauze pad and bandage over the wounds. From the exit wound, which was 1 inch in diameter, protruded a piece

of sloughing omentum, the margin of the wound being everted and raised over a circular indurated area. It was thought best to allow the sloughing omentum, which was very foul, to separate spontaneously, and then to return the stump. At the end of three weeks, however, the slough had not only separated, but the stump had retracted, and only a small granulating surface was left, which healed spontaneously."

FIG. 78.—Turko-Balkan War 1912–13. Bulgarian wounded by Turkish shrapnel at Kirk-Kalisse Fauntleroy collection.

FIG. 79.—Turko-Balkan War 1912–13. Bulgarian infantryman wounded near Adrianople.

From the Manchurian campaign, Lynch states that the shrapnel balls were prone to carry foreign material from the men's clothing into the wounds. From other sources we gather that shrapnel balls lodged in 66 per cent. of the cases. All wounds from this source suppurated. Wounds of the chest were often complicated by hemothorax, pneumothorax, and empyema—conditions which demanded prompt attention. Nearly all shrapnel shots of the abdomen died

Follenfant in the same campaign states that shrapnel wounds differed according to the part of the shrapnel that inflicted the

injury. Some of the shrapnels held the explosive in the head of the case. The latter and the metallic segments within, were broken and followed the cone of dispersion with the balls. The wounds naturally varied with the character of the missile—whether it happened to be part of the casing or the balls contained therein. The special feature of the wounds was their constant infection, as a result no doubt of the nature of the lesion, and the more frequent introduction of shreds of clothing into the wound. In the Turko-Balkan War of 1912–1913 the ratio of wounds by shrapnel has exceeded that of all preceding wars. Fauntleroy[1] our attache in the field, states that of 25,000 wounded received in the hospitals at Sofia from the battlefields of Adrianople, Kirk Kalisse and Lule Burgas and other engagements in the vicinity the shrapnel wounds averaged between 25 and 35 per cent. of the whole; that 86 per cent. of wounds from all arms were infected, and that 90 per cent. of the mutilating operations found necessary were the result of infection. His observations of the surgical wards of hospitals in Constantinople lead him to the belief that the ratio of shrapnel wounds on the Turkish side will be about 33 per cent. of all wounds inflicted at the battles of Kirk Kalisse and Lule Burgas, and that 60 per cent. of all those inflicted at Tchalgia were by schrapnel. Other observers[2] found the frequency of shrapnel wounds in the Constantinople hospitals as high as 80 per cent (Figs. 77 to 79).

WOUNDS FROM GRENADES, BOMBS AND MINES

Hand Grenades.—All the observers in the Manchurian campaign make note of the frightful wounds inflicted by the hand grenade. Hand grenades were used first by the Japanese at the siege of Port Arthur, but later they were used on both sides during the remainder of the war. McPherson saw many wounds inflicted by this device and they were difficult to treat satisfactorily. The wounds were multiple. The injuries were often caused by the shattering effects of pyroxylin gas. Parts were completely carried away or so damaged as to require amputation. Another class of wounds was caused by strips of the casing. These were deep, lacerated wounds, leaving ugly scars and causing much disfigurement when the face was injured.

[1] Report to the A. G. O., February, 1913, by Major P. C. Fauntleroy, M. C., U. S. Army.

[2] Lucas-Championierre, J. M. Chirurgien du Croissant Rouge, etc. J. de Med. et de Chirurgie Pratique, No. 24, Dec. 25, 1912.

The wounds were at first of a deep yellow color, the wounded suffered great pain, which persisted long after the wound had commenced to heal. Fig. 80.

Some of the wounds caused by the explosion of the grenades are described as very small and numerous, due to the lodgment of metallic particles. In addition to the physical injuries mentioned the worst effects of the explosion were moral. Only the best seasoned troops stood the fire.

FIG. 80.—Wound produced by explosion of hand grenade, Russo-Japanese War. (Lynch.)

Wounds from Bombs and Mines.—The wounds produced by bombs are similar to those arising from the high explosives already referred to. The injuries from terrestrial mines are also similar, with the addition of the lodgment of foreign bodies in the wounds, composed of gravel, dirt, and splinters of wood. The latter came from the boxes in which the explosive is buried beneath the surface. Such wounds are prone to develop the virulent infections arising from the bacillus aerogenes capsulatus and the bacillus of tetanus.

Wounds from Pistols and Revolvers.—Our remarks upon the subject of the stopping power of pistols and revolvers, and the illustrations exhibited in another part of this chapter bear to a large extent upon the characteristic effects of the wounds produced by the above-

named weapons. The calibers of these weapons usually vary between .22 and .47.6, the latter being used but seldom. The majority of the wounds come from .38 caliber bullets.

Projectiles from pistols and revolvers having lower velocities than rifle projectiles are less apt to fracture bone and they more often lodge than the bullets of the high-power rifles. As a rule the length of the pistol or revolver projectiles is much shorter than the longer stable bullet of the reduced caliber rifles. The length of the latter is usually four diameters; and for the smaller bore rifles, like the .25.5 caliber of the Japanese Army, the length of the bullet is as much as five diameters. The ballistician is wont to increase the length of his bullet as he reduces its caliber, and he does this to insure the stability of the bullet in flight, to keep it point on. This adds to both range and penetration, and for a military projectile it is very advantageous. The wound which such a bullet inflicts is generally round, corresponding to the caliber of the bullet. The channel is clean cut as it were, with a minimum of contusion, laceration and hematoma. The bone lesion is not so severe except for the proximal ranges. The epiphyseal ends of bones as we have already stated are generally perforated, with very little if any shattering. The pistol and revolver bullets on the other hand are much shorter by comparison. The length of any of them seldom exceeds two diameters and some of them, like the .45.5 caliber man stopper; the .45 caliber lead bullet with blunt point, the .38 caliber jacketed bullet for the automatic Colt's, are less than two diamteers in length. The bullets from pistols and revolvers are thus rendered very unstable as a rule. The least resistance on impact causes them to tumble, and then to crash through the tissues end over end, inflicting thereby uglier wounds, wounds exhibiting laceration, contusion, hematomata, and all the characteristics which favor the reduction of local resistance in the tissues.

Blank Ammunition and Toy-pistol Wounds.—Gunshot wounds from toy-pistols are of special interest to American surgeons, because they figure extensively in American surgical literature in connection with the production of tetanus. The same character of wound has been noted by Bonnette, Schernning and others abroad, with similar complications. As we will point out in the chapter on "Infection of Gunshot Wounds" the injuries from the toy-pistol and other blank ammunitions are usually delivered at close range. The impact of such a charge causes much laceration, contusion, hematomata—the very conditions that augment the tendency to the development of

the virulent infections. It is for this reason that toy-pistol wounds and wounds from blank ammunition deserve special consideration. Toy-pistol wounds in this country are inflicted accidentally about the time of the anniversary of our National Independence, and abroad the blank ammunition wounds occur about the time of the army maneuvers, in the sham battles which accompany these exercises.

Wounds from Shot-guns.—The characteristic features of wounds inflicted by small shot from the class of weapons known as shot-guns differ materially with the distance from the gun at the time of dis-

FIG. 81.—Radiogram showing lodged pellets from shot-gun wound. Compound comminuted fracture fibula. Loose fragments removed. Later infection from bacillus ærogenes capsulatus developed, necessitating amputation. Army Medical School collection.

charge, the size of the shot, the amount of propellant, the manner of loading or the kind of cartridge. The cone of dispersion made by the shot is influenced naturally by all of the foregoing, viz., the distance, size and number of the shot, the amount of propellant, etc. Close-range shots are marked by total destruction of tissues, laceration, hematoma and fracture of bone with extensive comminution, and by perforation and lodgment of individual pellets (Figs. 81 to 84).

Gunshot Wounds from Small Target and Flobert Rifles.—The bore of these weapons is generally .22 to .32 calibers. The projectiles may be round, or elongated, the latter being of two sizes, the long and

short. The weight of the projectile of the .22 calibers is about 15 grains, that of the latter about 60 grains. The velocity of the U. S. Army target rifle ammunition is 969 f.s. For a very interesting fatal case of gunshot injury of the head by the .22 caliber target rifle generally used in this country see Chapter VI, page. 170.

FIG. 82.—Radiograph showing lodged shot in upper thigh. Wounded accidentally by shotgun within distance of 4 ft. After the surgeons had removed all missiles in sight, over 90 pellets were revealed by X-ray. Army Medical School collection.

Doepner[1] gives some very interesting cases of fatal injury from the projectile of the Flobert rifle (Fig. 85). Fig. *A*, p. 113, is a deformed

[1] Doepner. Die gerichtsaertztliche Bedeutung der Flobert waffen. Aertzt. Sachverst. Ztg., Berlin, 1908, XIV., 349 ff.

Flobert rifle bullet which passed through the frontal bone of a girl nine years old, and perforated the brain with fatal results. Fig. *C* is a bullet that penetrated the left hip in a man sixty-eight years old. The accident was followed by fatal tetanus on the nineteenth day. Fig. *D* penetrated a rib and the entire lung, causing fatal

Fig. 83.—A radiograph taken in 1911 of James A. Stewart, Co. "I" 81st Ind. Vol. Inf., and "G" 45th Veteran Reserve Corps, who was accidentally shot in the right hand by a hunter, Feb. 8, 1857, the shot entering the wrist and palm of the hand. The fingers are strongly flexed, and there is considerable atrophy of the muscles. U. S. Soldiers Home collection, Dr. A. B. Herrick, X-rayist.

outcome from pleuritis and pneumonia. The other illustrations show deformed bullets from experimental shots on cadavers and boards.

Wounds by Air-gun Projectiles.—The projectiles of air-guns are about .22 calibers, round in shape, and composed of lead. The pro-

pellant is compressed air. The energy of the bullet is sufficient to penetrate the tissues and fatal wounds from air-guns figure in the literature. The bullet causes a more or less contused and lacerated

Fig. 84.—Radiogram in case of J. M. showing ununited fracture of humerus and lodged shot. Wounded June 25, 1860, by accidental discharge of shot-gun, distance 2 ft. Exposure made Oct. 1901. X-ray Laboratory U. S. Soldiers Home. Dr. A. B. Herrick, X-rayist.

wound. The knee, eye, and abdominal cavity have been penetrated by the projectile with disabling and fatal results.

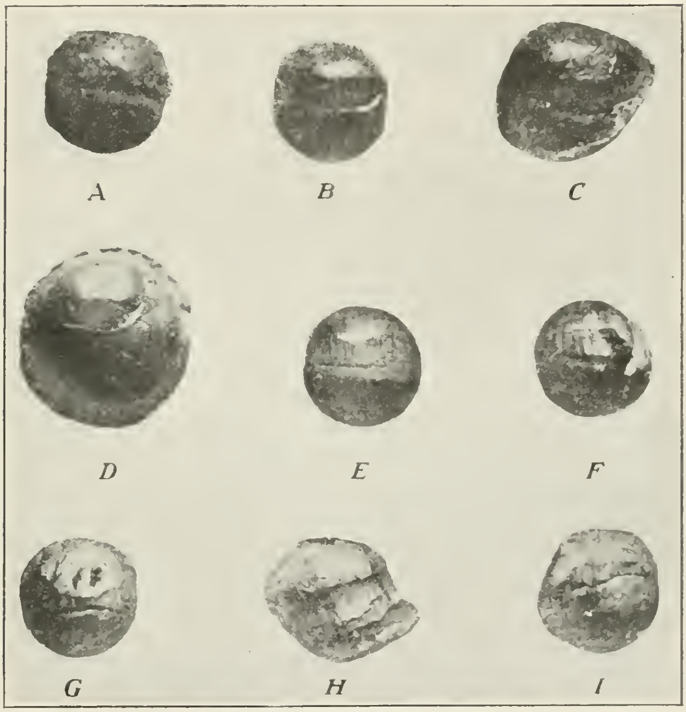


FIG. 85.—Photographs of Flobert rifle bullets magnified three and one-half times.

CHAPTER III

Symptoms of Gunshot Wounds

The symptoms of gunshot wounds are (a) pain, (b) shock, (c) hemorrhage, and (d) thirst. The first and last of these symptoms, viz., pain and thirst, are always present. Lodgment of a projectile, powder-burn and multiple wounds when present are usually referred to as complications of a primary nature, and not as symptoms.

(a) **Pain.**—The amount of pain after the receipt of a gunshot wound depends upon the situation of the wound, its gravity, and the amount of tissue involved in the traumatism. We have stated already that the amount of tissue involved is proportional to the velocity of the projectile, its sectional area, and the resistance which the tissue traversed offers on impact. Writers on military surgery have observed interesting cases of what is called referred sensation among the injured. Makins mentions the case of a man who was struck in the head who first felt pain in the great toe, and another who was struck in the abdomen felt pain in his foot only. A Civilian War Hospital[1] in the South African campaign mentions the case of a man who "fancied himself hit in the foot and at once sat down and proceeded to take off his boot with the intention of applying a first-aid dressing. His surprise was great when on taking off his sock he found no wound. He subsequently discovered that he was shot through the upper part of the thigh."

In the heat and excitement of battle men have been hit by the missiles of the old armament without knowing for a time at least that they were injured, and what is true of the old armament is true of the new, even more so. At Santiago we repeatedly questioned men who came from the front during the battle on this point. Some said they felt a sudden rap followed by a feeling of burning; or a blow, as from a hammer, a stone, or a cane. Others likened the pain to the sting of an insect. Many of the men stated that they did not know when they were injured and they were ignorant of the presence of a wound until their attention was called to it by a comrade, or the sight of blood. Pain when present was more often felt at the wound of

[1] A Civilian War Hospital by the Professional Staff thereof, etc. London, 1901.

exit. The wounded experienced a sense of stiffness about the part hit, which caused pain on motion and they preferred to remain quiet. Makins refers to an amusing instance of entire absence of initial pain in a man who was shot through the buttock, the bullet subsequently traversing the abdominal cavity. The patient was ignorant of having been wounded until on undressing he found blood on his trousers and exclaimed "why I have got this bloody dysentery." Nevertheless, the wound was so serious in its nature that he died as a result of it in thirty-six hours.

The sensation of pain is apt to be blunted to the point of anesthesia in wounds from solid shot, shell fragments, and the high-power rifle bullets at close range against resistant bone. In such cases the tissues are devitalized and there is a deadening of sensation in the injured part. In injuries of this magnitude there is always more or less shock, and the lack of appreciation of local pain may in some cases at least be due to the effects of constitutional shock.

(b) **Constitutional Shock.**—Military surgeons dwell on the train of symptoms of a depressing kind which is called shock, and which seems to be specially marked in gunshot wounds. In cases showing extensive injury like the wounds involving comminution of large resistant bone so common in shots by the high-power rifle at proximal ranges, in penetrating wounds of the large cavities, and again in wounds from the artillery class of missiles like shell fragments, or in the case of a limb carried away by a solid shot, there is commonly present an immediate disturbance of the nervous system which exhibits decided bodily and mental depression, the amount and duration of which is as a rule not proportioned to the gravity of the injury. The patient in most cases is seized with extreme pallor of the skin and mucous surfaces; the surface of the body is cold and clammy; a state of tremor, notably of the limbs, supervenes; the pupils are dilated, the heart's action is irregular, the pulse is weak, thready, irregular, and imperceptible at the wrist in marked cases; the respiratory movements are irregular and shallow, usually accompanied by deep sighing respiration; the features show mental apathy or anxiety and distress; there is impairment of superficial sensibility, and nausea and vomiting are often present. In the stress of battle there is often a kind of shock attended with great excitement and much restlessness, in which the movements of the patient are difficult to control, the reverse of the bodily and mental depression already referred to. We knew a vigorous young officer in the Sioux campaign of 1876 who was shot in the

head, wrist, groin, knee and twice through the body, who exhibited pallor and other symptoms of shock. When we first saw him he was carried by four men who held the four corners of a blanket on which he lay. He uttered piercing cries at the top of his voice, he labored under great excitement and talked incessantly. He was perfectly conscious, asked for water, and made an effort to give a message to be transmitted to his family, but he was soon seized with the wild agitation of a moment before and failed to finish the message. He continued in this restless state until death took place a half hour later.

In other cases the mental tension of the wounded whose temperament is at all times placid will apparently control or suppress a state of shock for an indefinite time after the injury. A captain of the 1st Cavalry in the Guaicemus fight in the Santiago campaign was shot through the body by a Mauser bullet. The bullet made a complete perforation of the body from back to front involving the right lobe of the liver and fracturing two ribs. He was conscious at the time that he had been hit from the flow of blood on his clothing and a sensation as if he had been struck by a stone, but he was engaged in aligning his men and correcting some confusion in his troop incident to a sudden volley after an ambuscade, and he completed what he had set to do before he was shot, and then, without ever falling to the ground he proceeded to the dressing station, a distance of 75 yards, where he placed himself under the care of a surgeon, after which a certain amount of shock supervened. He eventually recovered without operation.

The placidity of the Arab and resistance against shock is well told by Captain Engenio de Sarlo in the recent Italo-Turkish war in North Africa.[1] An Arab was wounded by the explosion of a grenade. There was a large abdominal wound, the omentum and a large mass of intestines protruding through the wound, with perforation of the protruded intestines in various parts, and entire ablation of the right hand. The wounded was in good condition when the reporter commenced to perform a laparotomy convinced at the same time that the operation would be of no avail. He sewed up a number of lateral tears and a circular rent in the intestines and left a drain after partially sewing up the abdominal wall; he then amputated by a circular flap in the lower third of the forearm. The wounded endured the various steps of the operations

[1] Le Caducée, Nov. 16, 1912, comments on the Report of Captain de Sarlo on the wounded at Derna by Ed. Laval.

without complaint, on the contrary, he thanked the operator for his services from time to time. Immediately after the operation he asked to be returned to his home where he was taken at once, and where he immediately sat down and commenced to eat some dates. No further mention is made of the case.

Sir Thomas Longmore, referring to cases where the temperament can exercise the faculty of control over alarm and depression, cites the case of a "sergeant who had the left arm completely carried off near the shoulder by a cannon ball at Waterloo. In this condition he started off and rode upright all the way from the field of battle to Brussels, a distance of 15 miles." On reaching the hospital he became utterly prostrate.

A temperament the opposite of the one just mentioned, one that is easily alarmed, may be overcome with shock after receiving a slight wound. In sush a case it is not easy to determine the symptoms of shock from those of fear and cowardice.

The duration of shock is variable and difficult to foretell. Some patients in profound shock will recover in a comparatively short time, while others in moderate shock may remain prostrate for an indefinite period, depending most likey on individual peculiarities.

Treatment of Shock.—There are some cardinal facts connected with shock which should be borne in mind:

(1) One wounded, in a state of shock, should always be carefully guarded by trained assistants when reaction sets in. During shock the weak condition of the heart often starts hemorrhage from injured vessels that bleed freely as soon as the blood pressure is re-established and the heart commences to regain its normal volume.

(2) When in a state of shock from severe injury the temperature falls to about 96.8° F., the prognosis is grave and the patient usually dies.

(3) All the wounded who fail to recover their temperature in about four hours, or in whom reaction is not in proportion to the depression, should be considered as seriously injured and unfit to undergo operation. "The thermometer is an unfailing indication as to when operative interference may be permissible" (M. Retard).

(4) Operations beyond ligation of vessels to arrest hemorrhage should be avoided during the state of shock, and transport, unless imperative, should be delayed.

The relief of shock is directed toward measures calculated to restore the blood pressure. The possibility of secondary hemor-

rhage should be remembered and the aim of the surgeon should be toward a gradual reaction. The first indication toward this end is the placing of the patient in the recumbent posture with his head on a level with the body, and restoration of the body temperature by the use of heat applied externally in the way of warm woolen blankets, hot-water bags, bottles, etc., with due care to prevent burns of the surface. Brandy or whiskey, diluted with hot water, should be gradually administered. An enema of 2 or 3 pints of normal salt solution is highly recommended by many surgeons. Transfusion of saline solutions in profound shock is often resorted to with marked results, supplemented by oxygen inhalations. Of the drugs in use, strychnia is one of the most popular, injected hypodermically. The Japanese in the Russo-Japanese War are said to have resorted to liquor camphoræ as follows: camphor 1 part, ether 4 1/2 parts, and olive oil 4 parts. This was used subcutaneously with marked benefit. It was the favorite remedy on the firing line.[1] In this country injections of adrenalin with normal salt solution are extensively employed. Four or 5 minims of adrenalin are dissolved at the time it is to be used in 500 c.c. of sterile salt solution to be injected in the cellular tissue of the flanks, buttocks or behind the breasts.

(c) **Hemorrhage.**—Hemorrhage as a symptom of gunshot wounds may be divided into (1) external primary, (2) recurrent hemorrhage, and (3) internal primary hemorrhage.

(1) **External primary hemorrhage** refers to hemorrhage that comes from injured vessels which are situated externally and which may be readily reached and ligated by the surgeon. Here we refer more especially to the vessels of the extremities and neck. Hemorrhage coming from the former situations, such as the vessels of the arm, forearm, thigh and leg, exclusive of the exposed vessels about the ankle and wrist, was considered very frequent once upon a time judging from the liberal distribution of tourniquets in the pouches of members of the relief corps. As a matter of fact external primary hemorrhage, under the designation mentioned, may be said to be rare. The Surgical History of our Civil War shows that primary hemorrhage only came under the observation of the surgeons in 5 per cent. of all wounds and in 3 per cent. in the Crimean War. Of the 1400 wounded at Santiago in 1898, the large majority of them being from the reduced caliber Mauser bullet, no death from external primary hem-

[1] Russo-Japanese War. Medical and Surgical Reports of Lt. - Col. W. G. McPherson, R. A. M. C.

orrhage was recorded and no vessel was tied on the field to arrest this kind of hemorrhage. The experience of the English surgeons in the Boer War agrees with the observations of surgeons in former wars. Makins,[1] referring to his experience in the South African War, states that external hemorrhage from the vessels of the limbs or even of the neck proves responsible for a remarkably small proportion of the deaths on the field. This statement may be made with confidence since it is not only his own experience, but it coincides with what he was able to gather from the experience of many medical officers on duty with bearer companies. He states that only one case of rapid death due to bleeding from a limb artery was recounted to him. This was the case of a man who was wounded in the brachial artery and who succumbed in 20 minutes, during the time that he was being transported to the dressing station. Col. W. F. Stevenson of the R. A. M. C., who was in charge of the line of communication in South Africa, states that "severe external primary hemorrhage from small bore bullet wounds of the vessels of the limbs, except when these are injured in regions where they are superficial, is uncommon."[2] Reports of Follenfant[3] on the Russian side in the Russo-Japanese War confirm the rarity of avoidable external primary hemorrhage on the field in the Manchurian campaign, and it may be stated as a paradox that nearly all observers in recent wars agree that blood-vessels are more often wounded with the use of the present armament than formerly, and yet external primary hemorrhage of an alarming kind, always rare in battle, is seen less often than ever before. The following explanation is given for this apparent contradiction: formerly when the large leaden bullet with a hemispherical head moving at a comparatively slow rate of speed collided with one of the larger vessels the latter was pushed aside and if it was cut across or otherwise injured, there was no great tendency to primary hemorrhage because of the irregularity of the wound in the vessel coats. The armored bullets of reduced caliber are more definite in the work which they accomplish; they cut the vessels like a knife because of their superior velocity, smaller caliber and more pointed, ogival heads. The mechanical effects of forcing the bullet through the tissues is done so rapidly owing to greater velocity that there is no time for the vessel to be pushed aside. When one of the large vessels is hit fairly the small caliber of the bullet

[1] Surgical Experiences in South Africa by George Henry Makins, F. R. C. S.

[2] Wounds in War by Col. W. F. Stevenson, R. A. M. C. Ed., 1910.

[3] Op. cit.

permits it to make two clean-cut perforations going in and out, leaving no lacerated edges. There is in such a wound, as far as the vessel is concerned, every opportunity for immediate fatal external primary hemorrhage. When the vessel is hit at a tangent a clean opening is cut on one side which again affords every chance for immediate hemorrhage, and fatal consequences would doubtless ensue in either case except for the following reasons: the channel of the wound being small, the narrow track is readily obstructed by a change in the position of the apertures in the muscles, intermuscular septa, fascias, etc., which causes obstruction in the continuity of the channel, hence the rarity of external primary hemorrhage from modern rifle bullets. In such wounds there may be no external evidence of hemorrhage, or possibly but a momentary spurt of blood, which is arrested as soon as the muscles change their position. Wounds of this character result in different kinds of aneurysms, which are more common in gunshot wounds now than hitherto, and which will be discussed under wounds of blood-vessels in another chapter.

(2) **Recurrent hemorrhage** may be external or internal. In this form of hemorrhage the temporary obstruction in the way of intervening layers of tissue or clot gives way and favors the recurrence of hemorrhage. Makins, in his extensive experience in the Boer War, noted the occurrence of hemorrhage in several cases in the lower extremities on the second and third days, which he styles recurrent hemorrhage and for which ligation of the popliteal or femoral artery became necessary.

(3) **Internal Primary Hemorrhage.**—We include in this classification hemorrhage that occurs from injury to blood-vessels in the large cavities, like the thorax, the upper and lower abdomens. The vessels in these localities have not the firm support of those in the limbs and injury to their coats by modern rifle bullets which make clean-cut perforations bleed freely as a rule. In such cases Makins[1] states that "the potential space offered by the peritoneal or pleural cavities favors the ready escape of blood from the wounded vessel, while the tendency of the blood effused into serous cavities to rapid coagulation is notably slight." The mortality from this source on the field of battle has always been considered very high before and since the change in the armament. Surgeon J. A. Liddell, of the U. S. Army, quoted by Otis, was convinced that a large proportion of the killed in battle perished directly from loss of blood as a result of internal primary hemorrhage.

[1] Op. cit.

Stevenson,[1] writing on the effects of present-day rifle bullets, believes that "it is much nearer the true state of the case to say that the great majority of those who die before succor can reach them succumb from primary hemorrhage. Some of the observers place the number of deaths from this cause as high as 85 per cent." The statement is not surprising to those who have been on the line and witnessed the death struggle of the wounded. Body wounds, when death is imminent, are always attended with extreme pallor, great thirst, fluttering pulse, lowering temperature, etc. These symptoms might well be ascribed to shock, but in the latter restoratives usually relieve the condition, while in body wounds in which internal hemorrhage is going on we find that restoratives avail nothing. The fatality on the field of battle to-day is greater than ever before. In the Civil War and the wars preceding it, the average of deaths to the number of wounded stood as 1 to 4 1/2. In the Manchurian campaign the proportion is as 1 to 3 1/2. Doubltess the greater fatality arising from internal hemorrhage after rifle wounds is one of the factors which adds to the battle mortality of the present. At the same time that military surgeons agree that the fruitful cause of death on the field comes as a result of primary hemorrhage, no accurate estimate of the percentage of deaths from this cause has ever been made for the reason that the surgeons are generally too much occupied in rendering aid to the wounded to devote any time to the dead.

(d) **Thirst.**—A drink of water is one of the first requests made by men wounded in battle. Thirst is always present and it is very much aggravated if the wounds are attended with hemorrhage. The fact that this symptom is more apparent in soldiers is doubtless due to circumstances which often precede engagements, such as (1) forced marches in summer with few opportunities to obtain water; (2) soldiers are taught to abstain from drinking because of the ill effects that indiscriminate drinking of water has on the endurance of men on the march; (3) exertion and loss of body fluids, perspiration, loss of sleep which induce a feverish state; (4) the ration in the emergent conditions of active campaign is usually made up of salt-meat and hard bread. All of the foregoing, with the excitement and din of battle, combine to excite the nervous system, and to produce thirst in the soldiery. The experienced military surgeon is always on the alert for means to provide water for the wounded, and among the many things he can do to alleviate suffering this is one of the most merciful.

[1] Op. cit.

CHAPTER IV

1. Infection of Gunshot Wounds; 2. Poisoned Wounds; 3. Tetanus and Toy-pistol Tetanus

(1) Infection of gunshot wounds has to do with the following:

(a) Sectional area of the projectile.
(b) Source of infection.
(c) Constitutional and local resistance.
(d) Virulence of microorganisms.
(e) Infection of wounds by modern armament.
(f) Environment.

(a) **Sectional area of the Projectile.**—In the earlier years of gun-making the projectiles used in hand weapons were of large caliber and since they were composed of soft lead the tendency for such bullets on impact against resistant structures was to still further increase their sectional area. The wounds that were thus caused possessed all the characteristics that favor the development of infection, viz., hematoma, contusion, laceration, etc. Later, the lead composing the bullets was hardened by an admixture of about 5 per cent. of antimony. But at about this time the improvements in gunnery added greater velocity and energy to the projectiles, so that the tendency to deformation when the bullet collided with resistant bone was still marked, and here again the wounds showed those characters that augment the disposition to infection. The relation between the original sectional area of a bullet and infection have always been marked for the reasons mentioned, and it is a matter of common observation that it is very much increased when the projectile flattens or disintegrates against bone, enough to disperse fragments in various directions. In such a case the metallic fragments acting as secondary projectiles cause additional laceration of tissue, contusion and hematoma.

In recent years the sectional area of rifle bullets has been very much reduced—from .45 calibers to .30 and even less—and the influence of lessening the sectional area has resulted in marked beneficence in the character of the wounds. Besides lessening the sectional area and also the weight of bullets, their hardness has been very much increased by enveloping the lead bullet in a mantle of hard steel. The tendency

to deform on the part of these compound bullets when colliding against the bony framework is very much reduced. The wounds—except at proximal ranges on hard bones—show fewer of the characters which formerly added so much to the development of infection. Such a bullet produces less traumatism in soft tissues, it perforates the joint ends of bones and, except when it is possessed with high velocity on impact against hard bone, it is apt to produce a wound having the nature of an incised wound comparatively free from the characters which lead to the development of infection as already pointed out.

(b) **Source of Infection.**—A gunshot wound may become infected in various ways. Infection primarily on the projectile itself may be carried into the wound, because, contrary to what has been taught by many, it has been amply shown that the act of firing does not convey enough heat to a bullet at any time to render it sterile.[1] Granting that a bullet is sterile at the time of firing, it can gather infection by ricochet, or by passing through intermediate substances and thereby infect a wound. Infection is nearly always carried into the wound with shreds of clothing, the amount of the latter usually being in proportion to the sectional area of the bullet. A bullet can gather infection from a dirty gun-barrel, and, lastly, the skin which is pierced or punched by the projectile invariably contains infected matter, which is carried in with the bullet. The foregoing is true of all projectiles fired from hand weapons, including the most perfect of the high-power military rifles for all ranges, at least from near the muzzle to 500 yards, as we have actually demonstrated by experiments on the target range, and no doubt the same is true of the maximum ranges for all hand weapons.

It is true that projectiles are sometimes found in original packages practically sterile and free from septic germs. This was especially true of lead bullets that were lubricated by dropping in hot boiling grease, but contamination is unavoidalbe in the ordinary act of handling and loading, so that it is safe to say that all bullet wounds are infected whether they show any marked evidence of such infection in a clinical way or not. A gunshot wound is certainly never bacteriologically clean.

(c) **Constitutional and Local Resistance.**—The general resistance of soldiers in arduous campaign is apt to be lower than normal, and

[1] Can a Septic Bullet Infect a Gunshot Wound? New York Medical Journal, Vol. LVI, No. 17, Oct. 22, 1892. Septic Bullets and Septic Powders, New York Medical Record, Vol. XVII, No. 25, June 22, 1895, by Louis A. La Garde, U. S. Army.

whatever depresses constitutional resistance in the way of privation and hardship is apt to induce susceptibility to the development of infection. Local resistance is largely determined by the mechanical effects of the projectiles causing the injury. Microscopic examination of the soft tissues surrounding the channel made by the bullet shows laceration, hematomata, and contusion, conditions favoring coagulation necrosis. In addition, dispersion of extraneous matter will be found, driven laterally by the energy of the projectile into the tissues to a distance of 17 mm., varying with the velocity and sectional area of the bullet.[1] This extraneous matter is lodged everywhere amid tissues wholely or partially devitalized. In such a condition the development of infection will be in keeping with the amount of traumatism and the virulency of the organisms which have found access to the injured part.

(d) **Virulence of Microorganisms.**—When dwelling upon the liability to infection in gunshot wounds, one should always bear in mind the mechanical effects of a rapidly moving body through tissues, otherwise it is difficult to understand the appearance of the so-called virulent infections in such wounds, as compared to what takes place in clean-cut wounds like those made by a keen knife blade, for instance, where there is no destruction of tissue about the seat of injury, no opportunity for the lodgement of extraneous matter or the presence of hematomata, contusion, laceration, etc. Welch, in his Shattuck lectures,[2] states that infection from the bacillus aerogenes capsulatus is most frequently seen in compound fractures, and next in gunshot wounds. The reason for this is at once apparent. The lesion in the two kinds of wounds, namely, a compound fracture and a gunshot wound, is very similar as regards the features favorable to the development of infection. In a gunshot wound we may state further that bone injury is not essential because gunshot wounds of soft parts still possess the features necessary for the development of the virulent infections at least.

In preantiseptic times the surgical wards of all hospitals were cursed by the ravages of pus-producing microbes. The experience of military surgeons was particularly distressing in this regard. In our Civil War, septicemia, pyemia, osteomyelitis, erysipelas, and

[1] Mutter Lecture.—Poisoned Wounds by the Implements of Warfare. Journal of the American Medical Association, April 11–18, 1903, by Louis A. La Garde, Med. Corps, U. S. Army.

[2] Boston Med. and Surg. Jour., No. 4, Vol. CXLIII, July 26, 1900.

hospital gangrene were the bane of all hospitals after great battles. Instead of amelioration taking place in the character of the infections as the war progressed, the tendency to their development in the most trivial injuries seemed to augment with the duration of the war. Those surgeons who survived to witness the dawn of antiseptic surgery, and the masterly way in which we avoid sepsis in wounds to-day, look back on their practice in the sixties with genuine sorrow. Robert F. Weir, who commanded the general hospital at Frederick, Maryland, after the battle of Antietam, while commenting on the treatment then in vogue, has made the following statement.[1] "For, looking backward, the surviving surgeons of that day must admit that they were unwittingly more fatal to those under their care than the battle was; that death followed the path of the surgeon, with his poisonous technique and dressings. What indeed was more provocative of infection than the care, for instance, of the sponges used at an operation? These were used repeatedly, whether for clean or septic cases, as we now say. Washed repeatedly, it is true, in fresh water, but, after all, germ-laden. Kept, too, soaking in water until again required, and producing millions of virulent germs, which, by the surgeons act, were at the next operation smeared freely over the wound. The Borgias never did as much! Though they knew what they were doing."

This is a painful admission and yet it is made by one whose life has been consecrated to the relief of human suffering, one of America's greatest surgeons. We now know that the surgeons of that time passed day after day from patient to patient planting and transplanting, year in and year out, with their poisonous technique, septic organisms from wound to wound, thus adding to their virulency with the duration of the war until the tissues showed a tendency to suppuration, slough, and the development of a gangrene which was then called hospital gangrene, the etiology of which is unknown and which only ceased to make its appearance about the time the war was ended. In addition to the virulence of the organisms that had been developed with time, the surgeons of that day dealt with gunshot wounds by the rifles of .55 to .70 calibers, the projectiles were made of soft lead weighing 450 to 760 grains, and they were animated with a velocity of about 1200 f.s. Wounds from such missiles were attended with extreme traumatism and the shells and canisters of the times were still

[1] Remarks on Gunshot Wounds of the Civil War, by Robert F. Weir, M. D., N. Y. State Journal of Medicine, 1904, No. 4, pp. 141.

worse in their destructive effects, so that everything in that era, the character of the wounds, the virulency of the microbes, and the ignorance of the surgeons, seemed to combine in adding to the horror of the situation.

(e) **Infection of Wounds by Modern Armament.**—Infection in war wounds with present-day armament, broadly stated, varies in frequency and extent with the character of the missile which inflicts them. Shells and shell fragments cause wounds attended with infection in modern wars as much as they did formerly. Wounds from this source require the unremitting care of the surgeon to arrest or curtail the infection which is invariably present. Hand-grenades, bombs, mines and pom-pom shells inflict lacerated and contused wounds which invariably suppurate when the wound is of any magnitude. The shrapnel balls cause wounds that suppurate as a rule. The ball is round, .50 calibers in diameter, composed of lead, weighing fron 167 to 288 grains. The contusion, laceration and hematoma which it invariably inflicts in the wound channel adds specially to the chances of infection. Modern rifle-bullet wounds exhibit less tendency to suppuration. The projectile from the reduced caliber rifle now carried by foot and mounted troops is about .25.6 to .30 calibers. It is made up of a core of lead encased in an envelope of hard steel, the whole bullet weighing from 150 to 220 grains. This bullet has caused the majority of wounds in recent wars and we find that wounds inflicted by it are for the most part apt to be humane and that they are prone to heal with but little, and at times apparently no suppuration. Still if one takes pains to carefully examine the tissues under the scab covering the wound of exit especially, he will generally find pus in wounds that are healing aseptically in the opinion of many surgeons. The wound of exit is generally larger than the wound of entrance, more lacerated, and the seat of this traumatism being in a dirty skin affords all the necessary opportunities for infection. In the Santiago campaign infection of the wound of exit from the Spanish Mauser bullet was the rule. In ricochet shots of soft parts showing irregular impact, suppuration was very prone to occur. Rifle-ball wounds attended with fracture of the long bones showed tendency to suppuration in proportion to the amount of comminution, the size of skin wounds, and attendant lacerations. Such wounds suppurated in spite of the proper application of the first dressing. Doubtless they would have had more chance for the introduction of additional infection without protection from the

clean dressing, yet if a virulent infection had entered such a wound with the projectile, the first-aid dressing could have remained of no avail to prevent the subsequent clinical history of such an infection, notwithstanding the oft-quoted saying of Prof. von Nausbaum that "the fate of the wounded rests in the hands of the one who applies the first dressing." When one considers that the rifle bullets which inflict wounds in modern wars are carried in dirty bandoliers and handled by dirty hands, that they are not sterilized by the act of firing, it should be the exception to find a wound in which healing takes place by first intention. When it does, it is because the wound is simple, in soft parts, through tissues having a well-developed local resistance, and not because the projectile is in any way sterile. Of the 1400 wounded in the Santiago campaign none of the virulent infections were noted, extensive suppuration from the ordinary pus-producing microbes was not often seen, and it was always easily controlled. The absence of severe infections has been very properly attributed to the wide use of the first-aid dressings carried by the soldiers and menbers of the relief corps on the line. The improper application of these dressings, as shown by the way in which they became loose and failed adequately to protect the wounds to which they were applied, when examined at the Base Hospital at Siboney, demonstrated conclusively that there were other factors which assisted in preventing suppuration. The battle was fought on the first of July in a tropical climate by an army that was embarked two weeks before at Tampa, Florida. Because of the overcrowded condition of the ships the Medical Department insisted on daily baths to the men. They were placed under the hose at certain hours, so that their skins were clean on landing. Khaki was the uniform, and the rainy season had set in, so that the air was washed of dust daily by afternoon showers. The foregoing and the small frontage of the Mauser bullet of the Spaniards, which carried but few shreds of clothing into the wounds, contributed largely no doubt to lower the percentage of severe infections.

Antisepsis and the use of projectiles of the reduced caliber rifle have combined to bring about marked beneficence in the war wounds of modern times. In the Civil War the mortaliity among those who reached the hospitals was 14.3 per cent. From the same class of cases the mortality was 6 per cent. in the Spanish-American War, 8 per cent. in the Boer War, and in the Russo-Japanese War it was 5.8 per cent. on the Japanese side and 3.4 per cent. on the Russian

side. The material reduction in the mortality since the Civil War, as already stated, is doubtless the result of the use of antisepsis and the change in the armament.

The results of Carl Reyher and von Bergmann, who were the first to employ antiseptic methods in military surgery in the field during the Russo-Turkish War of 1877–78 in wounds of the knee-joint, point strongly to the value of this mode of treatment in active campaign, and our results in the Spanish-American War bear as forcibly in favor of the humane projectile in wounds of the same bodily region. In the Russo-Turkish War the rifles of the combatants corresponded to the .45 caliber Springfield which we discarded in 1892. The 500-grain lead bullet having a velocity of 1301 f.s. caused great laceration of joints and epiphyseal ends. Up to the time of the happy results published by Reyher and von Bergmann the older surgeons unanimously practised amputation as the sole method of treatment in gunshot wounds of the knee-joint. This was the practice in the Crimea and that of the surgeons in our great Civil War and it was employed to cut short the ravages of sepsis. Reyher reports eighteen cases of wounds of the knee treated antiseptically, regardless of the extent of joint involvement, of whom three died, a mortality of 16.6 per cent. The treatment was strictly conservative without excision or amputation. The cases ending in recovery are said to have had movable joints. He employed irrigation in severe cases, while the more simple cases were cleansed externally and dressed with wet carbolic gauze. Von Bergmann employed the same method of treatment with the following results: Out of fifteen gunshot fractures of the knee, fourteen recovered in three of whom amputation was required. The fatal case was one of those in which amputation was practised. Nothing is said of the amount of motion remaining in the non-amputated cases. The majority of them more than likely got well, as did those of Reyher with movable joints. The cases treated by Reyher and von Bergmann occurred before the change in the armament of the nations had taken place. They represent, therefore, the results of injuries by the old soft leaden bullet of .45 caliber, weighing approximately 480 grains, treated conservatively under antiseptic methods. Grouped together we find that the mortality was for the two sets of cases only 11.1 per cent. Compared to the results of treatment of gunshot injuries by the old arm in the preantiseptic era the results of Reyher and von Bergmann were certainly a revelation. In looking over the statistics given us by Otis, we find that gunshot wounds of the knee in the Civil War

under all methods of treatment then in vogue gave a mortality of 53.7 per cent., which, compared to the results of Reyher and von Bergmann, places to the credit of antisepsis a total of 42.6 lives saved, in every 100 men hit in the knee.

In late years changes have come about in the manufacture and composition of rifle bullets to enhance the satisfactory results already alluded to, both as to life and limb. The character of gunshot wounds of bones especially is very much influenced by the density of the metals which inflicts them. Longmore,[1] among older writers, ventured to explain thirty-five years ago what would be the special features of gunshot wounds as soon as it became practicable to use steel bullets. The evolution of the military rifle and the missile it propels to-day have given us factors which in a humane sense stand next in importance to antisepsis.

The following table shows at a glance the successive results of gunshot wounds of the knee from the days of the Civil War to the present time.

GUNSHOT WOUNDS OF THE KNEE-JOINTS

CIVIL WAR, 1861–1865

Large Calibers minus Antisepsis

Mortality	53.7 per cent.		
Recovery	46.3 per cent.	Fit for duty	00.0 per cent.
Total	100.0 per cent.	Unfit for duty	100.0 per cent.

RUSSO-TURKISH WAR 1877–1878

33 cases by Reyher and von Bergmann

Large Caliber plus Antisepsis

Mortality	11.1 per cent.		
Recovery	88.9 per cent.	Fit for duty	00.0 per cent.
Total	100.0 per cent.	Unfit for duty	100.0 per cent.

REPORT SURGEON-GENERAL, U. S. ARMY, 1898–1902

76 cases

Various Calibers plus Antisepsis

Mortality	6.5 per cent.		
Recovery	93.5 per cent.	Fit for duty	39.4 per cent.
Total	100.0 per cent.	Unfit for dity	60.6 per cent.
		Total	100.0 per cent.

[1] Gunshot Injuries, by Sir Thomas Longmore.

SANTIAGO CAMPAIGN, 1898

17 CASES

Reduced Caliber plus Antisepsis

Mortality.........	00.0 per cent.		
Recovery..........	100.0 per cent.		
		Fit for duty.........	81.1 per cent.
Total...	100.0 per cent.	Unfit for duty.......	18.9 per cent.
		Total...........	100.0 per cent.

To Recapitulate.—(1) We find that the mortality of gunshot injury of the knee-joint in the Civil War was 53.7 per cent., and as amputation was universally done, all those who recovered escaped with the loss of a limb, unfit for duty; (2) that thirty-three cases of gunshot wounds of the knee produced by the larger caliber lead bullet in campaign, reported by Reyher and von Bergmann, treated antiseptically, gave a mortality of 11.1 per cent.; (3) that 76 cases produced by a variety of missiles reported by the Surgeon-General 1898–1902, similarly treated, gave a mortality of 6.5 per cent. and that 39.4 per cent. of those who recovered were restored to duty; (4) that of seventeen cases in the Santiago campaign by the reduced-caliber bullet the mortality was nil, and that 81.1 per cent. of the wounded recovered fit for duty. It is thus seen that the humane features of the reduced caliber bullet have operated not only in diminishing the mortality in gunshot injuries of the knee from about 6.5 per cent. to nil, but that it has increased restorations to duty 41.7 per cent. as shown by comparing the last two tables.

According to Stevenson the observers in the Boer War, both civil and military, report that wounds with the exception of compound fractures were wonderfully free from suppuration, "and that when it did occur it was only in a minor degree and that it seldom gave rise to general septic infection but only caused more or less delay in convalescence." Havard and Follenfant, with the Russian army in Manchuria, dwell on the frequency of infection of wounds by the Japanese rifle, which employs a projectile .256 inches in caliber, weighing 152 grains. Havard places the number of infections at 10 per cent. in the summer, and 90 per cent. in the winter. Follenfant says that 50 per cent. became infected in summer and 80 per cent. in winter. (Reyher[1] has noted this point not only for the Manchurian campaign but for all gunshot wounds occurring in

[1] Reyher, Dr. W. V., Vol. LXXXVIII, Archiv. für Klinische Chirurgie 1908–9.

winter because of the extra amount of clothing worn.) All shrapnel wounds were infected. Follenfant states that compared to the infections with the 11-mm. leaden bullet, which corresponds to our .45-caliber Springfield leaden bullet, weighing 500 grains, those by the small jacketed bullet are possibly not quite as frequent, they are more tardy to develop, more localized and less grave. Abscesses were not so frequent, febrile reaction not so intense, erysipelas more rare, and recovery after suppuration was more prompt. Death from septicemia was seldom seen, and he saw but one case of gas-bacillus infection, from a shrapnel wound of the thigh with a lodged fragment four days after the injury. The frequency of infection in the cold months is attributed to the heavy clothing worn by the Russian soldier, including a sheepskin overcoat. Extraneous matter was thus carried into the wounds by the force of the bullet against a dirty skin when the opportunity for bathing was not at hand. Major Charles Lynch, our observer with the Japanese army, places the tendency to suppuration of wounds in soft parts by the Russian rifle bullet at 60 per cent. "All rifle-bullet wounds with bone involvement suppurated. The tendency to suppuration of wounds in any tissue by the Russian bullet was thought greater than that found in wounds by the Japanese bullet and the reason is ascribed to the larger caliber of the former. Wounds by shrapnel, shell fragments, bombs, hand grenades, and deformed rifle bullets invariably suppurated."

(f) **Environment.**—Infection in gunshot wounds is apt to occur in proportion to the disturbance to which the wounded are subjected. In military practice enforced transport complicates the results of wound treatment materially. After great battles there is usually insufficient relief personnel; the wounded lie unattended for hours in varying conditions of weather and temperature. Gunshot injuries to bones and joints, which need absolute rest, are not always properly immobilized. Lengthy transport under such conditions in springless wagons over bad roads adds much to the probability of infection.

(2) POISONED WOUNDS

This is a subject so nearly related to wound infection that it can very properly be treated in this chapter. Reference to poisoned wounds is frequent in the literature of wounds by firearms.[1] The practice of poisoning implements of warfare like the spear, sword,

[1] The Mutter Lecture by the author, op. cit.

arrowheads, knives, javelins, etc., dates back to the days of the Greeks and Romans. A practice that is abhorred to-day and classed among the most cowardly deeds in the list of crimes seems to have been pretty generally adopted in ancient times. Poisoned arrows were used by the ancients against man and beast. The Celts in the hunt poisoned their arrowheads with a substance which was called *toxic*. After wounding a deer, for instance, the seat of injury was excised at once to prevent rapid decomposition. They also used hellebore and a substance called *limeum* which was known as deer posion. The Vandals who inhabited what is now North Germany used various poisons, aconite being the most deadly, and Claude Bernard states that the practice of poisoning missiles was employed in more recent times and in the Spanish Army as late as the reign of Phillipe the third. Some of the poisons, like curare, were said to cause death when introduced through a wound and they remained innocuous when ingested per os. Of the vegetable poisons most commonly employed, mention is made of extract of hellebore, aconite, yew, *limeum*, *ninum*, *helenium*. The nature of the last three of these is unknown to us. In this regard we may state that if all that is written of the lethal character of some of the poisons used is true, the ancients were past-masters in the practice of what is to us a lost art.

Among animal poisons used in modern times to poison missiles and cutting weapons for the hunt and in warefare by savage tribes in Africa, the South Seas, India, and China, may be mentioned decomposing viscera, and snake venum. Anthrax and curare are used by tribes in West Africa and the tropical water-ways of the Amazon respectively. The inhabitants of New Caledonia infect their arrowheads by dipping them in crab holes, and the experiments of Ledantec[1] showed that animals inoculated with the poison some months after the preparation of the arrowheads die of either tetanus or malignant edema, but more often the latter.

Our North American Indians poisoned arrowheads and bullets in a more varied but less deadly manner. The poisoning of the war implements was more often done during a period of self-torture and fasting by the young warriors during a war dance or a religious ceremony. The Comanches are said to have used the juice of the Spanish bayonet. The Sipares used the menstrual blood of a woman, while the Apaches prepared their poison by grinding the heads of rattlesnakes

[1] Origine Tellurique du poison des flèches des Naturels des Nouvelles Hebrides (Oceanie), Archives de Med, Nor. et Col., 1893.

with fragments of deer liver. The Moqui Indians irritate a rattlesnake to the point of madness. At this time it inflicts stings in its own body and the high priest of the Order of Snakes dips the arrow points or bullets in the bloody fluid. The poison thus prepared is said to cause death in three days.

Our own work with septic bullets and septic powders[1] has shown that microorganisms placed on projectiles or on powder grains are not destroyed by the act of firing. We fired bullets from different kinds of hand weapons which were previously contaminated with anthrax germs into susceptible animals at varying distances up to 500 yards and the animals died of anthrax in the majority of the cases. We also experimented with vegetable poisons, viz., curare and ricin, the latter being the most deadly of the vegetable poisons, and our experiments confirmed what appears in the literature, viz., the possibility of conveying poisons of any kind to man or beast by shooting.

Follenfant makes note of the frequency of malignant pustule among Russian soldiers seen in the hospitals in Mukden in the Russo-Japanese War, which, in a negative way, is of interest on the subject of wound infection. Cases were carried to the hospitals daily in January, 1905. The infection was attributed to imperfect tanning of the sheepskins from which their overcoats had been manufactured, the animals having died of *peste sibérienne*. No case of wound infection showing the septicemic form of anthrax was observed, and yet the spores of the organism were doubtless carried into the wounds by the projectiles. In connection with our experiments with anthrax balls on animals, already qouted, the observations of Follenfant are very interesting. The Manchurian campaign points in this regard to a fact already appreciated, namely, that man is not susceptible like some of the lower animals to the septicemic form of anthrax. His susceptibility is only skin deep, as it were, hence the malignant pustule. The latter no doubt arose from infection of abraded surfaces on the skin of soldiers wearing the infected sheep-skin overcoats.

(3) Tetanus and Toy-pistol Tetanus

This disease should have been considered with the virulent infections, but its history is so well identified with gunshot wounds in peace and war; its definite clinical symptoms and marked virulency for certain lower animals have made it of such value to experiment-

[1] Mutter Lecturer op. cit.

ers; and, lastly, under the term toy-pistol tetanus it occupies such a unique place in American literature that it deserves extended consideration, by itself.

The frequency of tetanus in war wounds has been attested by many writers. The following table from Nimier and Laval by Mathieu shows its occurrence in a number of the great wars, the general average being about one case of tetanus in every 300 wounded.

TABLE 4.—TETANUS IN WAR (BY MATHIEU)

Wars	Cases of tetanus	No. of wounded	Percentage
British Army in India (1782)	20	810	1/40 or 2.47
British Army in Spain (1811–14)	263	20,683	1/78 or 1.25
British Army in Crimea	26	12,094	1/465 or 0.21
Spanish Army in Morocco, wounded cared for in Africa.	1	56	1/56 or 1.78
Spanish Army in Morocco, wounded cared for in Spain.	4	3,920	1/980 or 0.10
French Army in Cairo (1798)	7	200	1/28 or 3.50
French Army before Constantinople (1836)	10	176	1/17 or 5.68
French Army in Crimea	120	39,868	1/332 or 0.30
French-Sardinian Hospitals (1859)	153	21,967	1/143 or 0.69
Prussian Army (1864)	14	1,968	1/140 or 0.71
Hanoverian Army after Langensalza (1866).	13	1,092	1/84 or 1.20
German Army (1870–71)	350	99,566	1/285 or 0.35
Austrian Army in Bosnia (1878)	16	3,878	1/234 or 0.41
United States Army, Civil War	500	246,712	1/488 or 0.20

In more modern times Schjerning, inspector general of the German Army, collected thirty-four cases of tetanus occurring in the German Army from 1881 to 1902 from wounds inflicted by blank cartridges. Bonnette[1] reports six cases in the French Army from the same class of wounds between the years 1892 and 1905. The blank ammunition of the German and the majority of continental armies is provided with a hollow wooden projectile, the others have a cardboard projectile simular to that in our army.

[1] Bonnette, Medecin Major, etc., Dangers des Tirs a Blanc, Paris, 1907.

Deubler[1] records twenty cases of tetanus in Maneuvers of the Austrian Army. Of this number seventeen occurred from accidental gunshot wounds by blank cartridges loaded with smokeless powder. The author points out the increase of tetanus since the introduction of the new explosive, but he attributes it to the wadding, which is larger and more carefully packed in smokeless powder cartridges to insure a louder report, the object being to simulate the conditions in war. Examination of the wads showed contamination but it is not stated that tetanus spores were found. As we will show later the source of infection was most probably not in the ammunition. We believe it would be more correct, in view of recent investigations, to attribute the occurrence of tetanus in these cases to special features in the lesion conferred by the explosive as well as by the wad, and to take for granted that the source of infection was infected dirt in the gun barrel, the clothing, or the skin at the point of impact.

The humane character of the wounds produced by reduced caliber bullets have led some writers to suggest that there would be fewer cases of tetanus in future wars. This would doubtless be true if the wounds were entirely produced by projectiles from the hand rifle. Unfortunately other implements which cause wounds attended with hematoma, laceration, contusion, etc., such as grenades, bombs, shrapnel, pom-pom shells, and shell fragments, figure in the battle casualties of the present day, and they will no doubt add to the opportunity for the appearance of tetanus among the wounded hereafter. Follenfant's observations in the Manchurian campaign on this point are of interest. He tells us that among the virulent infections tetanus was the most frequent. There were about three hundred cases with a mortality of 80 per cent. following the battle of Mukden, due it is said to poor transport facilities, and more especially to clouds of dust the last three days of battle. In the same campaign McPherson[2] also reports the tendency to the development of tetanus and malignant edema in wounds resulting from the destruction of bomb-proof shelters, especially those caused by splinters of the beams that support the earth sheltering. The common infections were also frequent in such wounds. He states further that infection of wounds by the non-virlent microbes in the army besieging Port Arthur was more common than in those of the field armies, but tetanus was mostly seen at Mukden. The number of animals with the mobile army doubtless contributed to contamination

[1] Verwundengofahigkeit der exercier-schusse Mittheilungen über Gregenstande des Artillerie und Genie-Wessens.

[2] The Russo-Japanese War, by Lieut.-Col. W. G. McPherson, R. A. M. C.

of the ground over which the army was constantly on the move: The favorite habitat of the bacillus of tetanus, as we know, is the intestinal track of the herbivora.

We are indebted to certain experimenters for our knowledge of the manner in which tetanus has become so intimately associated with the traumatism of a gunshot wound. The results of experiments by Lwowitch, Strick and Dorst[1] show conclusively that hematomata augment the susceptibility to infection. They injected tetanus in hematomata produced in rabbits by destroying the femoral artery subcutaneously with needles. By graduating the dose so injected it was found that compared to the amount necessary to produce lethal effects in a clean incised wound hematomata augmented the susceptibility one thousand fold. In regard to the susceptibility conferred by hematomata and the lesions in gunshot wounds, Strick found that the latter conferred greater susceptibility, and that the onset of symptoms in animals shot with tetanus balls is twice as rapid and death ensues earlier, due no doubt to the presence of hematomata and the state of devitalized tissues in and around the channel of a gunshot wound.

Toy-pistol Tetanus.—In this country the frequent occurrence of tetanus in men and boys who amuse themselves in celebrating the anniversary of our National Independence by the use of explosives in toy-pistols, fire crackers, torpedoes, etc., has called forth renewed attention to the source of this infection. The majorty of the cases have arisen from wounds by the toy-pistol, a .22-caliber revolver carrying six blank cartridges, loaded with an average of six grains of black powder, held in place by a paste-board wad. A study of the cases shows that they are grouped, as to time, about July fourth. Now that some of the state legislatures have prohibited the use of the top-pistol, the yearly number of cases is not so large as formerly. The boards of health of New York City and Chicago in three years time have recorded as many as 158 deaths, and as many as 400 deaths from tetanus have occurred for the whole of the United States in the course of one year. Health reports from a number of the cities show that 35 per cent. of

[1] Dorst: Over den invloed vanshet hæmatoom op het cptreden van infectie in die chirurgie. Ned. Tijdschrift voor Genees-kunde, 1896, 2. R., XXXII, 2 afd., 503–523.

Lwowitch (pupil of Kocher): unpublished work described by Tavel in Revue de Chirurgie, 1899, XIX, pp. 701–702.

Strick: Die Tetanusinfection, von Schusswunden und Hæmatomen ausgehend bei Kaninchen mit besonderer Berucksichtigung der Serum-Prophylaxis und Therapie. Inaug. Dissertation (Berne,) Cologne, 1899.

the cases have occurred in the month of July and that 41 per cent. of the cases have come from toy-pistol wounds.

The source of tetanus in wounds by blank ammunition was carefully studied by a number of observers. The work was directed toward the bacteriology of the powder and wads by means of culture methods and inoculations into aniamls. The powder was examined for accidental contamination, and, because so many observers had ascribed the introduction of the poison by the wad, we undertook a careful investigation of the possible contamination from this source. Although we found that the process of manufacture of card-board and other materials for wadding undergoes no treatment that is calculated to destroy resistant bacteria, and that they are manufactured from dirty rags, old paper, wood pulp, wool, etc., with every opportunity for contamination our examinations were altogether negative.[1] Our own examinations, those of the Director of the Health Department of Boston and other cities, those of Wells[2] of Chicago and others aggregating 675 samples of powders and wads, go to show that the bacillus of Nicolaier was absent in every instance and that the source of infection could not be ascribed to the blank cartridges.

In some experiments on animals we succeeded in communicating tetanus in 69.5 per cent. of the cases by methods as follows: The experiments were conducted with the .22-caliber toy-pistol. An artificial tetanus earth was made by mixing 1 quart of sterile earth with one agar-agar culture, after the toxin had been destroyed by heating at 65° C. for five minutes. The animals were shot in the fleshy part of the thigh.

(a) **Transmission by Infecting Black Gunpowder.**—One-half grain of tetanus earth was mixed with the powder in each of three blank cartridges with which three white rats were shot at a distance of 2 inches. Two out of the three animals developed tetanus and died on the fifth and sixth days respectively.

(b) **Transmission by Infecting the Wads with Tetanus Earth.**—Four wads were infected on their outer surface with a half grain each of the earth. Four rats were shot into as stated above. Two died immediately from shock and the other two succumbed to tetanus five days later.

[1] Mutter Lecture, by the author, op. cit.

[2] Wells, H. Gideon, M. D.: An experimental study of the origin of tetanus of the epidemic following July 4, 1899. Philadelphia Medical Journal, No. 1377, 1900.

(c) **Transmission by Placing the Earth on the Projectile.**—The latter were infected by placing the earth in three grooves running parallel with the long axis of the bullet. Three rabbits shot died with typical symptoms of tetanus on the sixth, seventh and eighth days respectively. Out of three guinea-pigs shot in the same way two died on the sixth and seventh days.

(d) **Transmission by Placing 1 Grain of the Tetanus Earth in the Barrel.**—Three white rats were shot at 2 inches with blank cartridges. Two of the animals died from tetanus on the fifth day.

(e) **Transmission by Shooitng a Blank Cartridge Through a Piece of Gauze Previously Contaminated with the Tetanus Earth, the Gauze lying Against the Part.**—Out of five white rats shot in this manner three succumbed to tetanus on the fifth and sixth days.

(f) **Transmission by Placing 1 Grain of Wet Tetanus Earth on the Skin of the Animal at the Point Penetrated by the Charge.**—Four animals were thus shot with blank cartridges, two dying of typical tetanus on the fifth and sixth days.

(g) **Transmission by Infecting Smokeless Powder.**—The powder was infected as stated under (a). Three white rats were shot at a range of 2 inches. One of them developed tetanus on the fifth day and eventually recovered. The other two were negative.

The control animals, shot in the above manner without the use of tetanus earth, gave negative results without exception. As stated already the fatality from tetanus attending these experiments aggregates 69.5 per cent. It is fair to assume that this percentage would have been greater with a pure culture of tetanus. The artificial tetanus earth was used to simulate the actual conditions under which tetanus infections usually occur.

We also found that in those cases where the shots were delivered at contact or thereabouts exhibiting burning or scorching from the ignition of the black powder, the development of tetanus was almost invariable, showing that the coagulation necrosis following burn augments the tendency to the development of tetanus infection.

From the foregoing we felt justified in attributing the occurrence of tetanus in toy-pistol wounds to the presence of infection in the contaminated dust of the street, which found lodgement on the clothing, hands, etc., of those who engage in the use of toy-pistols and pypyrotechnics.

Treatment.—The treatment of tetanus is (a) local, (b) constitutional and (c) specific.

(a) **Local Treatment.**—A gunshot wound with a degree of traumatism as easily accessible as that of a toy-pistol injury should be thoroughly cleansed with a liberal use of antiseptics. Every particle of foreign matter should be removed with soap and nail brush under an anesthetic. Loose tissues showing much laceration and contusion should be cut away with scissors. Before the wound is dressed antiseptically injections of 1 per cent. carbolic-acid solution should be practised as near the wound as possible and they should be repeated daily if tetanus supervenes. Some Russian observers have practised injections of emulsion of brain substance from small animals in the same way, after the symptoms of tetanus had set in with marked results. The emulsion is prepared by rubbing together under antiseptic precautions 10 to 15 gm. of brain substance from a rabbit or guinea pig with 30 c.c. of sterile salt solution, and then strained through a sterile cloth under slight pressure.

(b) Constitutional treatment includes supporting measures and medication. Among the latter chloroform by inhalation ranks first in controlling the painful spasms that characterize the disease. Chloral, bromides, canabis indica and opium have been used for the same reason.

(c) The specific treatment is most important as a prophylactic measure. Nocard and Welch first recommended prophylactic doses of tetanus antitoxin in veterinary practice with most profitable results. Doctor Alexander Lambert of New York City is a great advocate of the value of tetanus antitoxin as a prophylactic measure against tetanus in toy-pistol injuries. He cites the results of 1900[1] in New York where the Board of Health distributed antitoxin to the dispensaries throughout the city for use in toy-pistol and other injuries, without a single case occurring for that year's fourth of July celebration. Early and free use of antitoxin injections, as soon as possible after the initial symptoms have declared themselves, will reduce the mortality as low as 40 per cent. (Moschowitz). The dose should be repeated as often as may be indicated by the exacerbation of the symptoms.

When the antitoxin is used after the onset of the symptoms it is better to inject it into the spinal canal. The injection should be preceded by drawing 150 to 200 c.c. of the spinal fluid to about 10 to 15 c.c. of the antitoxin used. This injection may be followed by a similar one with a smaller needle along the large nerves leading to the seat of injury. The injection in the spinal canal may be repeated in about twelve hours.

[1] New York State Journal of Medicine, No. 4, 1904, pp. 146–7.

CHAPTER V

The Treatment of Gunshot Wounds

The treatment of gunshot wounds may be divided into the (1) Immediate, (2) Intermediate, and (3) the Remote.

(1) **Immediate.**—The measures of treatment to be observed in the immediate stage are (a) the treatment of shock, (b) arrest of hemorrhage, (c) the prevention of infection.

(a) The treatment of shock has already been discussed page 117. Chapter III.

(b) **Arrest of Hemorrhage.**—The opportunity to arrest alarming hemorrhage will depend upon the character of the hemorrhage—whether it be external or internal. In referring to the latter kind—internal primary hemorrhage, page 120, Chapter III—we called attention to the apparent increase in the cases of hemorrhage which occurs in the body cavities like the thorax and abdomen as a result of the use of reduced-caliber bullets. The treatment of internal primary hemorrhage is attended with great difficulty because it is usually accompanied by pronounced shock. Where life is jeopardized, an attempt should be made, in localities which permit of surgical interference, to cut down and ligate the bleeding vessels at the same time that all measures for the relief of shock are under way. External primary hemorrhage, as we have already stated, is rare. It takes place from vessels that are exposed or readily reached. But the ligation of bleeding vessels on the field of battle and in the emergent conditions which often obtain in peace is most difficult. Hemorrhage of a dangerous character rarely takes place in the presence of trained attendants and surgeons, when all the necessary facilities for operation are at hand. Until a favorable opportunity for interference has arrived, first-aid resources should be employed, and among these may be mentioned elevation of the injured part, extreme flexion, digital compression and antiseptic tampons. When the foregoing are not sufficient it is necessary to employ constriction, especially in gunshot wounds of the extremities. The dangers of such a method in the hands of laymen are very much minimized if the precaution is taken of rendering the limb practically bloodless by gravitation before constriction is made. Constriction may be accomplished with an elastic bandage, a Spanish

windlass, a pair of suspenders, or large handkerchief. The hospital corps pouches in the United States Army are provided with a strap of webbing holding a hard pad with a buckle attachment, to stay hemorrhage by constriction, while the orderly pouches which form part of the equipment for use of medical officers contain an elastic bandage 2 yards long and 2 inches wide. The constriction should be made rapidly, after the limb has been elevated, with sufficient firmness to control the flow of blood in the arteries and veins at the point of constriction. When pressure has been effectually applied as described it should not be maintained longer than 3 or 4 hours, to avoid danger from gangrene or paralysis. Such cases should remain under the watchful care of surgeons who are in possession of necessary hemostatic agents and equipment for ligation.

(c) **Prevention of Infection.**—The prophylaxis of infection in military practice has received a great deal of attention in recent years. The relief corps and the rank and file of all armies are drilled in time of peace in the methods of rendering first aid to the wounded, a great deal of which is devoted to the manner of preventing the introduction of sepsis into open wounds. Men under instruction are cautioned not to touch the wound with their fingers or to allow anything to come into contact with it except a clean dressing. Every soldier in the U. S. Army carries attached to his cartridge belt a first-aid package enclosed in a hermetically sealed metal case. The contents are made up of two bundles of absorbent sublimated (1 to 1000) gauze 4 by 84 inches long, two compresses of absorbent sublimated (1 to 1000) gauze, each composed of 1/2 square yard so folded as to make a compress 3 1/2 by 7 inches, two large safety pins wrapped in wax paper. The two compresses and the safety pins are wrapped together in tough paper in which are enclosed printed directions for use of the dressing. All the contents are sterilized in a metallic case 4 1/2 by 2 1/2 by 1 1/4 inches. The words "First-aid Packet, U. S. Army," are stamped on the metal case. Aside from the value of having these first-aid packets ready at all times on the line, the medical transportation is spared a great deal from the burden of carrying sufficient dressing material to meet all the emergencies likely to arise at the front, and much labor is saved at the dressing station when the slight wounds have been properly dressed on the line.

The first field dressing as described had one fault, which was unavoidable until very recently. Many observers, including the late Nicholas Senn, of Chicago, had sought to find a dressing that should,

first, be clean, and which should, next, sterilize the skin about the wound. Dr. Senn employed a field dressing which included in its contents a teaspoonful of a powder composed of four parts of boracic acid and one part of salicylic acid. Recently tincture of iodine has come forth as an ideal skin antiseptic in surgery. Colonel Antelo, of the Argentine Army, advocates its use very ably in an article in the Military Surgeon, for December, 1910, and it was used by some of the Russian surgeons very successfully in the Manchurian campaign. Grossich[1] was probably the first to formulate its use in general surgery. He recommends the painting of the field of operation with tincture of iodine to a clean skin just as the patient is going under the anesthetic; a second coat is applied before the incision, and a third coat is added whent the last suture has been applied. Major Woodbury, of the U. S. Army,[2] has advocated its use for some time for sterilizing the field of operation, the hands of the surgeon, the instruments and the ligatures. Other observers have used it in emergency surgery with the greatest benefit by applying a coat to the wound and the skin surrounding it without previous preparation, with the best of results. Hammer toes and ingrowing toe nails are operated upon in dispensaries and clinics with no previous preparation. Dr. John S. Neate,[3] microscopist in the Surgeon-General's Office, while working in the laboratories of the Army Medical School, has recently found that Lugol's solution may be effectually used in place of tincture of iodine. He has prepared a dressing which can be carried in a sealed glass tube. It is made of absorbent gauze first saturated with a strong solution of potassium iodide, and the gauze is subsequently impregnated with vapors of iodine crystals. When wet with water or blood the Lugol mixture furnishes all the antiseptic benefits of the tincture.

Fischer[4] states that the surgeons in the Manchurian campaign employed tincture of iodine to disinfect their hands and the field about the seat of injury. In the late Italo-Turkish War in North Africa Captain de Sarlo[5] states that tincture of iodine was very efficacious in preventing all infections and especially the virulent infections like tetanus and erysipelas.

[1] Centralb. f. chir., No. 44, Oct. 31, 1908.

[2] New York Medical Record, Feb. 11, 1911.

[3] For work of Dr. Neate on Iodine as a Skin Antiseptic see paper by Dr. J. Wesley Bovee, Proceedings 36th Annual Meeting American Gynecological Society.

[4] Archives de Medecine et de Pharmacie Mil., No. 48, 1906, by G. Fischer.

[5] Notes on the Wounded at Derna, by Captain Eugenio de Sarlo, Le Caducee, Nov. 16, 1912.—Ed. Laval.

Iodine has recently been adopted for field use in our army as follows: Iodine is put up in hermetically sealed glass tubes, each tube containing 1 gram of iodine and 1.5 grams of potassium iodide. Ten of these tubes are put up in a cardboard carton. Each hospital corps man carries one carton in his pouch, also a 4-ounce bottle.

By putting the contents of two tubes in the bottle and filling the latter to its shoulder with water or alcohol one is enabled to make a 2-per cent. solution, which is the strength recommended for first-aid use. The sealed tubes enter in the equipment of the field hospitals, ambulance companies and reserve medical supply depots. This method of carrying the iodine has the double advantage of a preparation ready for use as a watery solution or a tincture. Alcohol could not be carried in quantities by hospital corps men on the field, hence the advisability of having a mixture easily soluble in water and which can be employed with alcohol when this is available.

The greatest advantage of such a simple method of sterilizing the skin about the wound over the one that prevails in fixed hospitals, of scrubbing and washing with antiseptic solutions, lies in the fact that water in bulk of suitable quality is seldom found in active campaign.

The iodine tincture or solution is painted over the wound and adjacent skin, being careful not to allow the preparation to collect in recesses of the wound when they are present. The iodine when allowed to collect in pockets is very irritating and its presence is a detriment. The wound is next dressed with the first-aid dressing previously described. In large lacerated wounds the contents of several of the first-aid packets may be used or in the case of shell wounds, we carry in the United States Army a field dressing as follows: (1) a compress composed of 1 square yard of absorbent sublimated (1-1000) gauze folded to make a pad 6 by 9 inches; (2) one bandage 3 inches wide by 5 yards long of closely woven absorbent gauze (1-1000) rolled and wrapped in parchment or waxed paper, and (3) two No. 3 safety pins wrapped in waxed paper. The whole dressing is wrapped in tough paper with proper directions for use printed thereon. Short bandages are sewed to the compresses for the purpose of temporarily fixing the latter on the wound, after which they are firmly bound to the parts by the roller bandage.

The field dressings of all armies are about the same, since they are intended to subserve the same purpose. The dressings are absorbent and protective in design. An abundance of absorbent dressing, is of special value to the military surgeon in field practice. By

covering the wound completely with plenty of absorbent dressing, and in cases of deep lacerated wounds if the dressing is loosely packed in the wound, drainage will be maintained until a favorable opportunity for redressing. In the case of large wounds when the time for redressing is indefinite, as often occurs in the emergent conditions of active campaign, cotton batting should be used over the absorbent dressing to protect the wound from outside contamination. With such a dressing it is possible to carry the wounded over several days until a field hospital has been reached, when all facilities are at hand for antiseptic and operative work.

Immobilization.—Fixation of wounded parts plays a great rôle in gunshot wounds as a prophylactic against infection. When enforced transport is necessary, as so often happens in military practice, it adds much to the comfort of the patient in keeping down pain; it tends to prevent the recurrence of hemorrhage, and it favors early healing.

When soft parts alone are wounded we immobilize by means of slings, a firmly fitting bandage, or splints to keep the wounded part at rest. In the case of wound of the chest or abdomen we apply a firm bandage about the body to check respiratory movements.

Immobilization is also of special value in gunshot fractures. As soon as the first dressing has been applied fixation of the fragments is accomplished by woven wire splints, which are carried in the pouches of the relief corps men, also by extemporized methods such as immobilizing the fractured arm or forearm to the chest by bandaging the member to the body. In fracture of the lower extremity in military practice, in the absence of anything better, we improvise splints from folded blankets, gun scabbards, bayonets or rifles.

Immobilization in all bone lesions, whether there is distinct solution of continuity or not, should invariably be practised, and especially so after lesion from the armored bullets. These hard projectiles, when hitting the joint ends of the long bones, and also the diaphyses, in the mid ranges, have a tendency to perforate or gutter a bone without causing complete fracture. Transport and handling of a limb so injured without immobilization endangers the occurrence of fracture and other traumatisms, which augment the danger to infection. Such an injury should be treated by permanent fixation at once and it should not be handled unnecessarily. Many of these lesions, especially in the diaphyses, consist of perforation with subperiosteal fissures extending in the long axis of the bone

and when the overlying support gives way from jolting, jarring or undue handling, fracture takes place. This fact was referred to in our report to the Surgeon-General in 1893, when we tested a German silver 30-caliber jacketed bullet in cadavers under the orders of the War Department.[1]

In the living the case of Major T. J. W., 10th U. S. Cavalry, wounded at Santiago, is most applicable. He was wounded at 6 P. M., July 1, while in the standing posture looking through his field glasses. He felt a sharp blow on the left thigh which whirled him around. In endeavoring to pick up a pipe-stem which had fallen from his hand he fell to the ground and called for assistance to place him over the crest of the hill out of the line of fire. Wound of entrance by a Mauser bullet was found located at lower angle Scarpa's triangle and the wound of exit just below the rim of the pelvis on a line drawn from the center of the rim to the greater trochanter. The ball pierced the trousers pocket and a pocketbook therein and emerged from the skin, lodging in the trousers near the point of exit, where it was recovered. The passage of the ball through the thigh was from within, and below upward. A surgeon dressed the wound temporarily at once and applied splints from above hip at loin to ankle outside, and an inside splint from crotch to ankle. Fracture was diagnosed. After about one hour he was carried on an improvised stretcher to a dressing station about 3/4 mile to the rear. No redressing was done here and splint was not disturbed. The same night he was transported on a stretcher 4 miles to the field hospital where about 1 A. M., July 2, the wound was dressed and leg again examined and fracture diagnosed by a second surgeon. The splints were reapplied and left on for two days more. A third examination was made when thigh was pronounced not fractured and the splints were removed. July 10 splints were reapplied and the patient was transported 7 miles over a rough road to the Reserve Divisional Hospital at Siboney. We were in command of the Division Hospital at Siboney and in charge of the evacuation of wounded. July 11, the day after arriving from the front, we had Major W. and a great many wounded loaded on the hospital ship Relief. His thigh was then in splints, the same as those applied on the day before in the field. The celebrated Surgeon Nicholas Senn of Chicago, then Lt.-Col. of Volunteers and consulting surgeon with the army in the field, examined this officer while he was in the Division Hospital at the front and he gave it as his opinion

[1] See Annual Report, Surgeon General, U. S. Army, 1893.

that there was no fracture. Two radiographic plates were made on the hospital ship Relief by Doctor Wm. M. Gray. Fig. 86 is made from the skiagram of one of the plates. It shows no fracture, but part of the greater trochanter gives evidence of guttering in the line of flight of the projectile from below upward.

Fig. 86.—Case of Major T. J. W. 10th Cavalry, showing grooving of the trochanter major. Army Medical School collection.

July 26 patient was transferred from the hospital ship Relief to the New York Hospital. On admission the limb had no splints. A fluoroscopic examination showed an oblique fracture through base of neck and part of greater trochanter with abundant callous and much displacement. The limb was found to be flexed and shortened 2 1/2 inches. Wound exit was closed, wound entrance was suppurating slightly. No crepitus, no false motion, considerable tenderness and

swelling about knee-joint. September 15 discharged from New York Hospital, with good motion of limb, shortening 1/2 inch. Took to crutches September 6, could bear some weight on injured leg. Major W. made a good recovery later and became a General Officer. The complete fracture took place after Doctor Gray's radiographic plate was taken on the Relief.

The injury to the bone was made by a Mauser bullet which had lost some of its remaining velocity because it was lodged in the clothing as stated. It perforated the cancellous tissue of the greater trochanter which, like the epiphyseal ends of bones, exhibits perforation rather than fracture, especially with lower velocities. The mistake made was in taking off the splints before his admission to the New York Hospital. We know so much more about the effects of reduced-caliber bullets now that such a mistake is not likely to occur hereafter.

The measures calculated to prevent infection in the early treatment of gunshot wounds may be summed up as follows:

1. The first dressing should be sterile, applied over a surface that has been painted with iodine.

2. No attempt should be made to disinfect the wound proper on the battle field.

3. Probing for bullets or the use of even a sterile finger in a wound is absolutely prohibited.

4. The severely wounded, and gunshot fractures should not be transported unnecessarily.

5. Immobilization when indicated should be practised at once, and in bone lesion with or without fracture it should be maintained until firm bony union has occurred.

(2) **Intermediate Treatment.**—The intermediate treatment is done in a field, base or well equipped hospital in military or civil practice. It should be preceded by a thorough examination and the measures of relief to be instituted will be guided to a great extent by the X-ray evidence as well as the local and general symptoms. In accordance with the findings the measures of treatment will include redressing of wounds, the proper use of disinfection and drainage, the treatment of existing infection, removal of foreign bodies, and loose fragments of bone; excisions, amputations, laparotomies, administration of food and stimulants, ligation for aneurysm, hemorrhage, and the treatment of secondary hemorrhage.

Simple gunshot wounds by the armored reduced-caliber bullets require no additional treatment after the application of the first field

dressing. At least that was our experience at the Reserve Division Hospital at Siboney after the battle of Santiago. The wounded commenced to enter the hospital late on the day of battle and continued to arrive for several days thereafter. The simple wounds, in which the bullets had traversed unimportant soft parts, were covered by dry blood clots and they were healing under the first field dressing. In the majority of the cases the latter was renewed, although there seemed to be no indication for this expenditure of valuable time and extra dressings, except in those cases where the dressings had become disarranged.

No attempt should be made to invade the bullet's track for the purpose of sterilizing the wound. As we have already stated in the chapter on Infection of Gunshot Wounds, all the wounds of this class are of necessity infected. During the earlier use of antiseptics, surgeons essayed the use of antiseptics in gunshot wounds as they did for unclean wounds generally, with unfortunate results.

To determine the effects of antiseptic measures upon the track made by a bullet, Müller and Koller made interesting experiments upon rabbits. They tried varying methods of treatment in wounds inflicted by projectiles that were primarily infected as follows:

1. Controls for which nothing was done.
2. Those treated with glass drain.
3. Those treated with an iodoform-gauze drain.
4. Those treated with 5 per cent. solution carbolic acid.
5. Those treated by swabbing with a cotton mop soaked in tincture of iodine.
6. Those treated by cauterizing the track from the wound of entrance to the wound of exit.

All the wounds were dressed with a clean sterile dressing. The results showed that the wounds treated with simple dressings did best of all, and that those treated by the radical measures mentioned, such as swabbing with tincture of iodine and the application of the cautery, gave evidence of active suppuration in every instance. Von Bergmann's first efforts to treat gunshot wounds in war radically ended disastrously. In the early part of the Russo-Turkish war he disinfected, drained, and dressed antiseptically, but his results were disappointing in the extreme.

The vain efforts of these investigators are easily explained by experimental evidence. In some tests already referred to we found that carbon particle, when rubbed on the skin of rabbits which were next

shot with weapons of various calibers, were driven as far as 17 mm. into the tissues surrounding the channel of gunshot wounds, and that the distance to which tissues may be so invaded depends upon the velocity and sectional area of the bullet. From the foregoing we have to assume that infection of any kind which finds lodgment on the ball, the clothing or skin, would be dispersed similarly and that all attempts to reach such infection by the ordinary means of cleansing must end in failure. Speaking generally, we should be content to treat a gunshot wound by the application of tincture of iodine, and the first field dressing at the earliest time practicable after the receipt of the injury. In such cases one has to rely on the local and general resistance of the individual to ward off the development of infection. That such a course is wise and proper is shown by the prompt healing in the large majority of simple gunshot wounds by the projectiles of ordinary hand weapons.

Examination of Gunshot Wounds.—The old-time method of examining gunshot wounds with bullet detectors and probes of various kinds has been made obsolete, in military surgery at least, by the use of the steel-clad bullets that do not lodge as often as the old leaden projectiles. Again we depend upon the use of the X-ray to locate lodged missiles of all kinds and to interpret bone lesions, which often determines the necessity for or against operation. The rule of cutting down in all cases of gunshot injury for diagnostic purposes is unnecessary. The position of the fragments can be ascertained by a study of a Röntgen ray plate for all practical purposes. As long as the wound remains aseptic the fragments of bone will retain their vitality and they will serve a useful purpose in the healing process. There are only two indications for cutting down upon a gunshot wound. The first is in the case of a lodged missile after its location by the X-ray, and the second is in case of gunshot fractures when infection has appeared or is threatened by the pressure of many loose fragments.

Removal of lodged missiles more properly belongs to the Remote Treatment and it will be dealt with under that head.

When a gunshot fracture of the upper or lower extremity becomes infected the surgeon should cut down boldly and practise *debridement* with all the significance that the meaning of the word bore for the older surgeons who employed it in the days when sepsis was the rule in all wounds. Thorough tubular drainage, removal of free and infected fragments of bone and any lodged material, and the liberal use of disinfectants should be practised. Frequent irrigation with bichloride

of mercury 1–4000 or carbolic acid 1–40 should be resorted to, or, if intermittent irrigation fails, continued irrigation with a saturated solution of acetate of lead as recommended by the late Nicholas Senn[1] should be employed. Infection in gunshot fracture is often difficult to treat successfully because infected areas are inaccessible. Whenever thorough drainage is obtained the septic condition disappears in a short time under irrigation as mentioned. As soon as union has commenced to take place extension and counter-extension or the fracture box should be replaced by a properly adjusted plaster of Paris cast, and as early as possible the patient should walk or be rolled into the open air.

The author has purposely withheld comment on the different bullet detectors and extractors because their use is not contemplated in the modern treatment of gunshot wounds. Nélaton probes seldom have application as detectors because the projectiles now are made of hard metals which leave no mark on the porcelain tip. The telephone probe is uncertain in its mechanism and often misleadng. Bullet extractors are superfluous and their place is easily filled by the many different forceps in the armamentarium of the surgeon. Extraction of a bullet through the track which it has made should be avoided in all cases. To tamper with these already contused and lacerated tissues only spreads existing infection and it adds to the danger of systemic infection by breaking up the lymph barriers that nature is establishing to prevent it. If it is necessary to remove the projectile, in the intermediate stage, after it has been definitely located, it is better to cut down de novo under strict antiseptic precautions and thus remove the projectile from its place of lodgment. Our experience following the battle of Santiago demonstrated that the patients themselves were restless until the lodged missiles were removed. In this battle 10 per cent. of the rifle-bullet wounds had lodged balls, a fact that was explained largely by the uneven topography of the terrain, and an abundance of underbrush between the opposing armies. The majority of the projectiles removed gave evidence of indentation or other deformation from ricochet. We were short of dressings in the extreme, and the orders were to refrain from removing lodged balls except in cases of actual necessity, an order which we regret to state was not always complied with by the operating staff.

[1] The Modern Treatment of Gunshot Wounds in Military Practice, The Military Surgeon, 1898, by Nicholas Senn, Lt. Col. U. S. Volunteers.

Administration of Food and Stimulants.—The value of proper food and stimulants to the wounded can only be appreciated by those who have witnessed their effects on men who have been wounded in battle which, as frequently occurs, has been preceded by fatiguing forced marches, loss of sleep, and lack of food. As often happens the wounded have lost blood, and they have suffered pain and many discomforts in transport. Under these trying conditions men are in a low state of nutrition and vital power. Their resistance to microbic influences is much impaired and they are specially downcast in spirits. At such a time nothing is more indicated than food of a nourishing and stimulating kind. At Siboney after the battle of Santiago, we had a staff of helpers whose office was to supply the injured with beef tea, hot gruel, chocolate, tea and coffee. We had captured a wine cellar on landing, which served the wounded with good burgundy, claret and sherry when required.

In our Army, field, evacuation and base hospitals are provided with hospital stores for the sick in the way of beef-tea, brandy, chocolate, condensed milk, malted milk, rolled oats, soups, green and black tea, and whiskey. The dressing stations are supplied similarly. The effect of these necessary and kindly attentions to the wounded is magical. They become conscious of the presence of substantial help about them. Their hopes are raised and their despondency is replaced by good cheer.

Inattention to the details of early feeding after great battles is one of the fruitful causes of death. Surgeons in the field should make special efforts to provide themselves with the articles mentioned when the battle is impending; the good results thereafter will be in keeping with the preparations made in advance. The allowance on the supply table should be no guide, it should be multiplied many times if opportunity offers.

Hemorrhage.—As stated already, severe external primary hemorrhage of the kind that requires ligation of vessels, from present-day rifle bullets, is uncommon. It was not common with the old armament and it is thought to be less so with the new. Of the 1400 wounded at the battle of Santiago no death from external primary hemorrhage was recorded and no vessel was tied on the field to arrest this kind of hemorrhage. The experience of the English surgeons in the Boer War and the reports of Follenfant on the Russian side in Manchuria confirm the rarity of avoidable primary hemorrhage on the field.

At the same time that this kind of hemorrhage is specially rare with out present armament, as we will explain when treating of aneurysm and injury to blood-vessels, injury to the latter is more often seen. The vessels are often grazed, their coats are partially destroyed and the remaining support gives way causing a hemorrhage later. These cases occur in the intermediate stage of the management of gunshot wounds, and they are to be dealt with at the field or base hospitals. Here also we are apt to have cases of recurring hemorrhage in wounds where the temporary obstruction, like intervening layers of tissue or clot, give way with the recurrence of bleeding. Most generally these cases have to be treated by ligation, an operation which can be more properly performed at a field hospital where the necessary facilities and trained assistants are at hand.

Secondary Hemorrhage.—Thanks to antisepsis secondary hemorrhage is now comparatively rare in war hospitals. As this form of hemorrhage is mostly due to the invasion of septic organism into wounds, it was common in preantiseptic days and it caused great mortality. With our present methods of dressing wounds, we prevent sepsis, and it may be said that secondary hemorrhage from septic conditions is now as rare as it was common before. However, the traumatism incident to the mechanical effects of a bullet traversing soft and bony tissues will leave conditions at times that cause secondary hemorrhage independently of sepsis: (a) a specula of bone adjacent to a vessel, in transport may by its pointed, irregular or jagged edge, lacerate or cut an artery and thereby set up hemorrhage; (b) a vessel's coats may not be entirely cut away, and here again the hurtful effects of enforced transport are seen. A vessel whose coats are cut away, excepting the intima, should be kept as quiet as possible, but the emergent conditions in war often compel transport, and the jolting and jarring in all kinds of vehicles, over rough roads, tend to cause hemorrhage by rupture of the remaining barrier.

The treatment of secondary hemorrhage is (a) by ligation of the vessel in the wound, (b) by ligation of the main artery of the limb, (c) by amputation.

When secondary hemorrhage first takes place a tourniquet should be applied and an antiseptic tampon should be packed in the wound under firm pressure. As soon as proper preparations have been made the surgeon should open up the wound under antiseptic precautions and search for the bleeding vessel with a view to its ligation. In securing the vessel the surgeon should satisfy himself that he is

applying his ligature to the healthy part of the vessel wall, because the coats of an artery in septic cases are apt to undergo slough, like the rest of the tissues. The wound should next be thoroughly drained and cleaned by irrigation with antiseptic solutions like mercuric bichlorid 1–4000, acid carbolic 1–40, etc.

In those cases in which the bleeding vessel cannot be found, or where there seems to be oozing from one particular locality the actual cautery is indicated. The same resource may be employed where it is difficult to find a healthy vessel to tie conveniently. The latter may be seared with the cautery at a point where it appears healthy, provided it is not too large. In wounds of the extremities the practice is to cut down upon the main artery and tie on the proximal side of the wound. If hemorrhage still persists or if gangrene sets in, a misfortune not uncommon in the lower limb, amputation is next in order. Proximal ligations succeed better in the upper extremity, but the rule there also is to amputate, if the hemorrhage recurs after ligation. Amputations are often performed in military hospitals under these circumstances, because of exigencies in military practice that might be avoided in civil hospitals where the surgeon has entire command of the environments. To persevere and temporize in the military service means time, dressings that are often scarce and attendants whose services are necessary for the alleviation of suffering to a greater number of wounded. Under such circumstances it is the safer course for the sake of the one whose limb is in jeopardy to amputate, and dress, rather than to persist under difficulties, with no assurance of succeeding perfectly. The harm that may be done to one wounded is compensated for by the greater amount of good that comes to those who might be otherwise neglected.

Whenever it is possible to command the movements of patients it is better to keep the serious cases, at least, as quiet as possible. Those who have lost blood and who have sustained operations should receive supporting treatment of a special kind.

(3) **Remote Treatment.**—In the later or chronic stages of gunshot wounds it often becomes necessary to operate for removal of foreign bodies after their location has been definitely ascertained by X-ray examination. The removal of necrosed bone, once the source of a great deal of protracted suffering in gunshot wounds, has to be practised occasionally nowadays, in old wounds, as a result of infection which persists or recurs from time to time.

The correction of deformities and restoration of loss of function

from injury to certain anatomical parts will come in for a certain part of the after-treatment, such as plastic operations to correct deformities following cicatrization of extensive wounds and burns, and the restoration of function by the operation for severed tendons and nerves. Of the many disabling and remote consequences of gunshot injuries, the lodgement of foreign bodies is probably the most common. These are to be removed by surgical operation whenever practicable.

CHAPTER VI

Gunshot Wounds of the (1) Head, (2) Face and (3) Neck

1. **Gunshot Wounds of the Head.**—The ratio of gunshot injuries of the head to the total number of casualties in battle has always been relatively high, but it has increased very much with the rapidity and accuracy of fire of modern arms. According to Longmore the head and face offer a target area of 5.89 per cent. compared to the target area of the rest of the body. If men fought standing the percentage of head wounds to the total number of casualties would correspond very closely to the above ratio. In modern wars the tactician drills his soldiers to fight under cover as much as possible. As a consequence the head is exposed to fire longer and more often than the remainder of the body. Again, in siege operations and fighting from entrenched positions the head and upper part of the body are necessarily more often and longer exposed so that the ratio of head wounds is relatively higher among those defending fortified positions. The Crimean War is cited by writers as a typical example of the effects of fighting behind entrenchments, and as a result 20 per cent. of all the gunshots treated were of the head, face, and neck.

The Spanish-American War, in which siege operations figured but little, gives a fairly good idea of the frequency of head wounds in modern wars. In 4756 gunshot injuries in all parts of the body, the head, face and neck were injured in 15.26 per cent.[1] of the total. Fischer[2] gives 20 per cent. of head wounds for all gunshot injuries in the Manchurian campaign.

Gunshot wounds of the head may be divided into (a) those of the scalp; (b) shot wounds of the skull without lesion of cranial contents such as, contusion, guttering and fracture of the outer or inner table alone; (c) shot fracture of the skull with attending brain injury.

(a) **Gunshot Wounds of the Scalp.**—Contused or lacerated wounds of the scalp are rarely fatal. Out of 7739 scalp wounds by gunshots in our Civil War, Otis reported a mortality of 2.09 per cent. The fatalities are attributed to erysipelas, meningeal inflammation, gan-

[1] Annual Report S. G., U. S. A., 1900.

[2] Archives de Med. et Phar. Mil., No. 48, 1906, p. 102.

grene, tetanus, pyemia, etc. Doubtless some of the fatal cases of wounds of the scalp, as pointed out by certain authors, include lesion of the skull that is not easily determined. Thus Chenu reports a mortality of nearly 10 per cent. in 1633 contusions and simple wounds of the scalp among the French troops in the Crimea. The divergence of the figures given by the two authors would indicate that a certain percentage of the French wounded had suffered from unrecognized cranial injuries.

From present-day military rifle bullets, wound of the scalp per se, as a result of superficial glancing and grazing shots, should be attended with no mortality. Writers from the Boer War observe that grazing shots exhibited loss of substance, "the skin being actually carried away by the bullet" (Makins). Scalp wounds from shell fragments and shrapnel are irregular and lacerated. The wound is larger as a rule than those made by the rifle bullet and they are more prone to infection.

Treatment of Shot Wounds of the Scalp.—No class of wounds should receive greater care in the primary dressing than head wounds. The dirt of the scalp is constant, and no scalp wound escapes infection. The surgeon's aim from the first should be directed to minimize the amount of infection present in the wound. In active campaign and during other emergent conditions the surgeon has in tincture of iodine a great aid for the subjection or prevention of sepsis. The hair should be either shaved or cut as short as possible with scissors. Short subcutaneous tracts should be laid bare by connecting the wounds of entrance and exit. The adjoining skin and wound should be swabbed with a 50-per cent. solution of tincture of iodine, followed by the application of a first-aid field dressing. In field and base hospitals where all the facilities for wound dressing are at hand, thorough scrubbing with nail brush, soap and water and the liberal use of antiseptic solutions should precede the application of the primary dressing.

(b) **Shot Wounds of the Skull without Lesion of Cranial Contents.**—In this class of injuries we have contusion of the skull with fracture of the outer or inner table alone. The following table from the Records of the Civil War by Otis is full of interest for a consideration of the subject of cranial injuries by gunshot in these days of clean surgery and the change in the implements of war. The table has served all writers in discussing head injuries since it was written, because of the richness of the material, and the masterly analysis of it by the great author.

GUNSHOT INJURIES OF THE CRANIUM

Results of 4350 Gunshot Injuries of the Cranium Reported During the War of the Rebellion

Injuries	Cases	Recovered	Died	Undetermined	Ratio of mortality
Contusions of the skull.........	328	273	55	....	16.8
Fracture of outer table alone (?)	138	128	10	....	8.7
Fractures of inner table alone....	20	1	19	....	95.
Linear fissure of both tables.....	19	12	7	....	36.8
Fracture of both tables without known depression.	2911	1001	1826	84	64.6
Depressed fractures............	364	231	129	4	35.8
Penetrating fractures...........	486	68	402	16	85.5
Perforating fractures...........	73	14	56	3	80.
Eerasement or crash or smash...	9	....	9	....	100.
Contre-coup (?)................	2	1	1	....	50.
Aggregates................	4350	1729	2514	107	57.7

Contusion of the Skull.—The vast majority of contusions of the skull in former wars were inflicted by slow-moving lead rifle bullets. The change of the armament has rendered them less frequent in recent wars, and they will be the result henceforth of impact from shrapnel balls, slowly moving shell fragments, and spent rifle balls. In such cases the periosteum is lacerated and the bone is more or less contused.

Fracture of Outer Table Alone.—Gunshot fracture of the external table of the cranium alone has been especially rare. The instances on exhibition in the vast collection of skull injuries from the Civil War in the U. S. Army Medical Museum, at Washington, relate to fracture of the outer table of the frontal sinus, the mastoid, and zygomatic process of the temporal bone. Now and then a grooving of the outer table of the vault is found produced by the sharp angle of a shell fragment. Wherever injury to the outer table occurred in other regions of the skull, the inner table was also involved. What was true of this injury by the old armament is alike true of the same injury by the new. We have never seen a gutter fracture of the skull of the outer table, from jacketed bullets of reduced caliber in the living, or in cadavers from experimental shots, which did not show splintering

of the inner table. This fact has also been noted by observers in recent campaigns although Stevenson and Makins each report a case from the Anglo-Boer War.

Fracture of the Inner Table Alone.—Gunshot fracture of the inner table alone, occurring from direct violence to the outer table, has been noted by military surgeons generally. Otis refers to ten specimens in the Army Medical Museum from the Civil War and the returns give account of twenty cases in all. Figs. 87 to 90. Makins saw no case of the kind in the Boer War. We have no knowledge of such an injury by the jacketed missiles of the present day. Of the twenty cases reported by Otis fourteen were caused by oblique impact of musket balls, four by shell fragments, and one by a buck shot. The velocities imparted to projectiles in that day compared to those of the present time were low, the projectiles themselves were non-penetrating, obtuse bodies, with sufficient energy on impact to cause the outer table to yield temporarily with resulting fracture of the inner table. The superior velocity and penetration of the jacketed rifle bullets of the present day tend to fracture the outer and inner tables at the same time, and they penetrate the skull to an extent proportional to the amount of their remaining energy.

(c) **Gunshot Fracture of the Skull with Attendant Brain Injury.**—In this class of wounds the inner or both tables have been fractured with injury to some of the cranial contents resulting. They are most important because of their fatality; the prompt and radical measures of treatment that are often necessary; and also on account of their complications and sequelæ.

Fatality of gunshot injuries of the cranium with concurrent brain injury has always been relatively high. Grouped as a whole in accordance with the plan in Otis' table, the fatality in the Civil War was 59.2 per cent., in the Franco-German War 51.3 per cent., and in the Spanish-American War and Philippine Insurrection 51.6 per cent.

In the Anglo-Boer War Stevenson gives the results of head injuries as follows:

	No. cases	Recovered	Died	Death rate per cent.
Gutters	63	51	12	19
Penetrations	13	8	5	38.4
Perforations	60	37	23	38.3
Totals	136	96	40	29.4

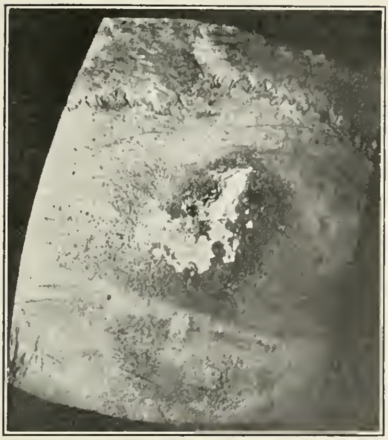


FIG. 87.—Photograph of outer table of skull showing contusion without fracture by a conoidal musket ball.

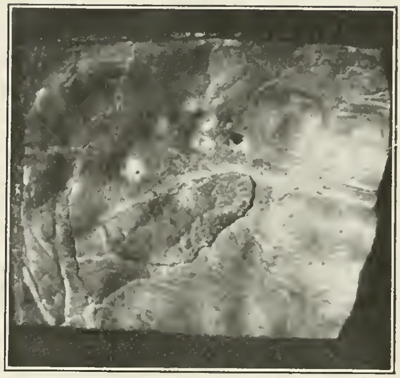


FIG. 88.—Inner table of same skull with fracture. A fragment an inch and a half in length and half an inch broad completely detached from vitrious table. Specimen from Civil War 1861–65. A. M. M. collection.

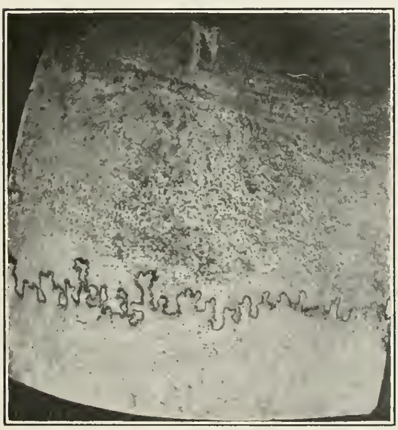


FIG. 89.—Photograph of gun-shot contusion outer table of skull without fracture by a conoidal musket ball.

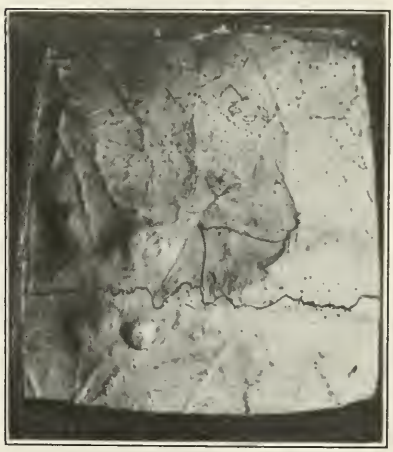


FIG. 90.—Inner table same skull showing fracture with depression opposite the point of contusion on outer table. Dura was lacerated. Specimen from Civil War, 1861–65. A. M. M. collection.

For the Russo-Japanese War Follenfant,[1] writing of the statistics in the Kharbine hospitals for 1904, gives a mortality of 29.5 per cent. in seventy-one gunshot fractures of the cranium with brain lesion, and a mortality of 10.2 per cent. in 263 fractures without brain injury. Doubtless the latter suffered brain lesion in a certain percentage of the cases as the mortality is rated too high for this class. In dwelling upon the rather low mortality, 29.5 per cent. and 29.4 per cent., among those who suffered with brain injury in these two recent wars, we have to remember that Kharbine and the English base were far from the front and that the statistics are culled from a restricted class. Per contra we have to account for our relatively high mortality, 51.6 per cent., in the Spanish-American War by citing the fact that our statistics were made up from all cases coming under treatment, a class without restriction as to time, the extent or location of injury. We have reason to believe that the Anglo-Boer War and Kharbine statistics refer only to cases that reached hospital care after the lapse of some days.

Gutter Fractures.—This form of injury is especially common with the use of steel-jacketed bullets. The ogival headed bullets of

Fig. 91.—Gutter fracture of first degree. The drawing does not show well the small fragments of bone usually carried from the margins of the depression by the bullet. (Makins.)

this class travel in a straight line, they are not deflected like the old lead balls. In the minor degrees of guttering the outer table is grooved by the projectile, carrying away small bone fragments. As these particles of bone become displaced with great violence they take up part of the energy of the bullet and force themselves

[1] Op. cit.

into adjoining soft parts. The scalp is slit in superficial bone fractures, but the more frequent injuries are deeper, they exhibit oval wounds of entrance and exit which mark the limit of the bullet's track. The shock of impact is so violent in the deeper gutter fractures that the vibratory force invariably fractures the inner table and the amount of comminution it sustains is generally greater than that seen in the outer table. Gutter fractures of the type mentioned occur in all parts of the cranium, they are characteristic of jacketed bullet wounds, and under prompt and radical measures of treatment the prognosis is very favorable for head cases. The following diagrams from Makins represent the different degrees of gutter fractures and superficial perforating fractures by the modern bullet. Figs. 91–96.

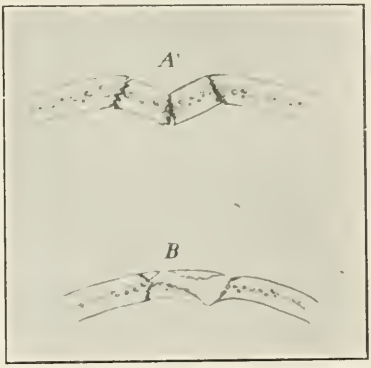


Fig. 92.—Diagrammatic transverse sections of varying condition of bones in gutter fractures of the first degree. A, with no loss of substance; B, with comminution. (Makins).

Penetrating Fractures.—In this class of skull fractures there is a wound of entrance and no apparent wound of exit. The missile is generally lodged within the skull unless it has, as sometimes happens, passed down the neck. Again a non-penetrating lead bullet, impressed by low velocity, may have flattened and lodged against the skull, producing fracture in and about the area of impact, or it may have bounded back through the entrance wound in the scalp.

Penetrating fractures were more common in the days of the old armament. The surgical records of the Civil War make note of 486 cases with a mortality of 85.5 per cent. The majority died at once or soon after reaching field hospitals. Many cases of recovery with lodged balls within the cranium are reported, and some were reported to have been restored to duty with balls lodged in their cerebrum, "but the diagnostic details accompanying the histories of these cases are not sufficiently precise to invite the fullest confidence" (Otis). Missiles were successfully extracted from within the cranium in eleven cases. In one instance the wounded was an officer who remained on active duty ten years afterward, while the others were discharged the service and placed on the pension rolls.

Fig. 93.—Gutter fracture of the second degree. Perforating the skull in the center of its course. External table alone carried away at either end. (Makins.)

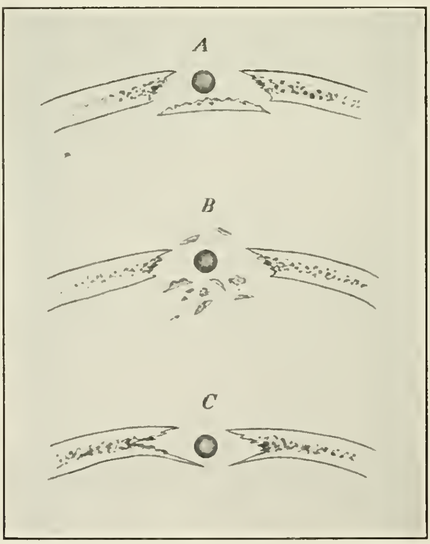


Fig. 94.—Diagrammatic transverse sections of complete gutter fracture. A, external table destroyed, large fragment of internal table depressed. (Low velocity or dense bone.) B, comminution and pulverization of both tables center of track. C, Depression of inner table (low velocity). (Makins.)

Of thirteen cases of penetrating gunshot fractures reported by Stevenson from the Anglo-Boer War the bullet lodged in nine cases, with five deaths. Of the four who recovered, the bullet was extracted in three cases and remained lodged in one case. The latter is referred to as a "surgical curiosity." "Trooper M was admitted to No.

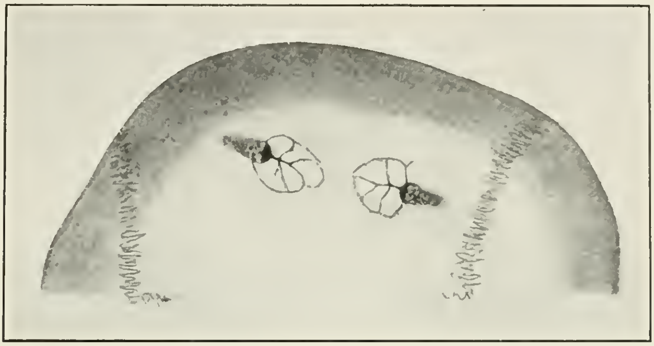


Fig. 95.—Superficial perforating fracture. Illustrating lifting of roof at both entry and exit openings. (Makins.)

13 General Hospital for a gunshot wound of the scalp. A shell had exploded within a few yards of him, and he believed he was hit on the forehead with a stone, but this proved to be incorrect. There was a small dry scab over the middle of the frontal bone, and beneath it an almost healed wound through which, however, a probe passed into

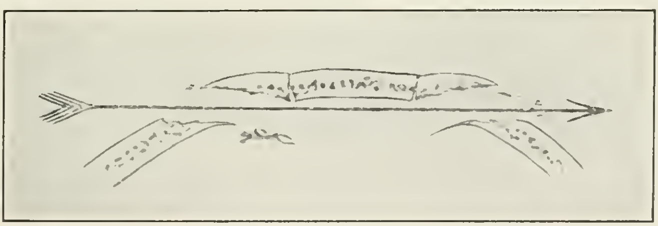


Fig. 96.—Diagrammatic longitudinal section of fracture shown in Fig. 95. (Makins.)

the cranial cavity. There were no brain symptons, and the man expressed himself as being "perfectly well." Brain symptoms appeared on the sixth day; the temperature went up, the patient became very restless and quite unaccountable for his actions. A trephine was applied at the side of the wound; the dura was found lacerated; several loose pieces of bone were removed, and a drain put in. All

symptoms disappeared and the case did well until the sevententh day. Signs of brain irritation then again set in, and there was evidence of pus under the scalp above the right ear; the scalp was incised, giving exit to a considerable quantity of pus. It was then discovered that there was a fracture of the skull at this situation and that the pus came from an abscess of the brain. The trephine was again

Fig. 97.—Latest skiagram of John Gretzer showing present location of Mauser bullet in brain. Exposure made in 1912, thirteen years after injury. Army Med. School collection, Gibbs Laboratory. Dr. Leon T. LeWald, X-rayist.

applied, the abscess washed out and drained; complete recovery followed. A skiagram showed a rifle bullet at the base of the brain."

The following case from the Spanish-American War is of even greater interest since it is accompanied by a photograph and skiagram recently taken.

"Case 14.—Penetrating, Mauser-bullet wound of brain; wound aseptic; bullet not removed.

"John Gretzer, Jr., private, Company D, First Nebraska Volunteer Infantry, wounded at long range, March 27, 1899, at Mariboa, Philippine Islands, by a Mauser bullet entering cavity of cranium, 3/4 inch above the supraorbital ridge and 1/4 inch to the left of the median line. There was total loss of consciousness during first few hours following receipt of the traumatism, with the exception of a few short intervals of semiconsciousness, at which time excruciating pain

Fig. 98.—Photograph of John Gretzer, Jr., late Pvt. Co. "D," 1st Neb. Vol. Inf., taken thirteen years after receipt of injury. Scar from wound entrance shows on forehead above inner canthus, left eye. Army Med. School collection.

in the head was experienced. The patient was taken to the First Reserve Hospital at Manila, where he lay in bed for about four weeks. While in bed, he suffered extremely from pain in the head, most severe the first three days, moderating slightly at the end of the fifth week, becoming intermittent, greatly exaggerated on exertion, by heat, and especially by direct rays of the sun, exposure to which caused him to reel, stagger, and almost lose consciousness. At the present time (August, 1899), is still quite susceptible to direct rays

of the sun. First few days of illness were marked by extreme nausea and persistent vomiting; the slightest thing taken in the stomach would be rejected. The pain in the head increased the severity of these attacks. During early weeks of illness any exertion of the brain, as reading, caused pain in back of eyes and vertex of the head.

"Returned to San Francisco with his regiment in August, 1899. Radiograph taken August 20 showed Mauser bullet embedded in left occipital lobe."

"Condition October 1, 1899, six months after receipt of the injury: Occasionally has pain in the lumbar region, and describes it as being a "catch," lasting about five minutes at a time. Pain in the head, when present, is located a little anterior to parietal eminence on left side. There is no history of loss of power on either side, but a weakness is appreciated in the right arm and leg, and a slowness in response to mental impulse. This last is demonstrated in the act of writing; though the thought is perfectly clear, there is a slowness in the forming of the words."

"Voice: Patient did not, to his knowledge, exercise this function for first two days of illness, but on beginning to do so, noticed a slight confusion of ideas, it being necessary to first clearly fix a thought before giving expression. There was also temporary loss of power to recall past events and names of companions. This returned with full clearness at other times. A slight confusion still remains."

"Eye: Pain back of left eye more or less severe, and increased by use, and relieved by closing the lid. During confinement to bed following injury, patient tested vision of left eye by closing right. The vision was clear, but slight weakness and photophobia were noticed. Ptosis of left eye was marked during early weeks of illness. Aperture is now smaller than that of right eye. A slight diplopia was also present, a line of printing appearing double. Pupils are regular, but left slightly larger. Reaction to light and power of accommodation is noticeably decreased, especially in left eye. Visual field normal. No nystagmus."

"Hearing is normal. Sense of taste more acute on right side, the anterior two-thirds of left side showing marked dullness.

Tactile sense seemingly slightly dull on right side. General sensation of right side not as acute as on opposite side.

"Reflexes: Knee reflex very marked on right side, responding to touch above, as well as below the joint; the contact from finger causing a disagreeable tingling throughout the thigh. On left side, reflex is

exaggerated, but not to such a marked extent. Wrist reflex marked on right side, causing a chronic spasmodic contraction of the fingers. Reflex absent on left side. Ankle clonus and patellar reflex absent. Cremasteric marked on both sides. Sphincters uninvolved at any period of illness; coordination good, though a slight uncertainty is felt on attempting to walk with the eyes closed. No epileptiform seizures. No disturbance of nutrition or bodily functions.

The patient later entered the mail service and returned to Manila on duty."—Reported by Major A. C. Girard, Surgeon, United States Army, General Hospital, Presidio.

Mr. Gretzer is now employed as a clerk in the Postoffice Department. In a recent letter he writes of his condition as follows:

POSTOFFICE DEPARTMENT,
Office of the Inspector in Charge,
New York, N. Y., Oct. 13, 1911.

Colonel Louis A. La Garde,
Commandant, Army Medical School,
Washington, D. C.

My dear Sir:

I am in receipt of your favor of the 9th inst. relative to gunshot wound of head, received by me during my army service in the Philippine Islands. I regret that I am unable to furnish you with a medical history of my case since leaving the Presidio General Hospital.

I have not received medical treatment for my wound, as I realized aside from an operation but little relief could be afforded, and my condition has not justified that, inasmuch as a consultation of army surgeons at the Presidio Hospital decided that an operation would probably prove fatal. The symptoms from which I suffer as a result of bullet carried in brain are about the same as when discharged, except stooping causes severe pains in the head. This is also true of a sudden jar. My wound appears to be affected by a change in weather. General health good.

I will be pleased to furnish you any further information desired, and appreciate the interest you have taken in my case. I am enclosing a couple of newspaper clippings in connection with my case, which may be of interest.

Yours sincerely
(signed) JOHN GRETZER, JR.

The following case exhibiting a lodged Krag-Jorgensen bullet is taken from the records of the hospital Madison Barracks, New York: J. S. Powell, Pvt. "K" Company, 9th U. S. Infantry, aet. 28, admitted July 23, 1903. "Accidentally shot by firing party at 500 yards range, ball ricocheting on butt timber and striking patient while in target pit at Stoney Point Rifle Range, New York, July 23, 1903, as per transfer slip."

Diagnosis at Hospital.—"Gunshot fracture skull, right parietal region, Krag-Jorgenson bullet, severe, causing partial hemiplegia, left side. Entrance wound 4 inches above right external auditory meatus and 4 inches from right external angular process of frontal bone, ball penetrating brain, no exit wound." Under chloroform anesthesia numerous pieces of bone were taken from the entrance wound, a bleeding vessel was ligated; brain lacerated, bullet not found. Scalp wound was sewed with silkworm gut and dressed antiseptically. Sent to quarters August 23. The patient was later discharged the service, but he was readmitted to the same hospital June 3, 1904, for cerebral abscess posterior part parietal lobe. He died the same day. At autopsy ball was recovered on the tentorium in the position indicated in the skiagram, Fig. 99. After discharge from the service Jan. 28, 1904, the patient suffered from partial paralysis left side face, and left hand; headache, and vertigo, for which he was borne on the pension rolls until his death June 3, same year.

The vital parts of the brain are sensitive to all projectiles, large or small. The following case exhibits the effects of a diminutive bullet impressed with comparatively low velocity when traversing the brain at the base:

Fig 100 is from a skiagram which shows a .22-caliber lead bullet lodged in the brain substance. It was fired from a target rifle with suicidal intent by Corpl. C. 29th Company Coast Artillery Corps, U. S. Army. The muzzle was held against left temple. The ball entered 2 c.m. above middle of left zygoma; traversed the left temporal lobe, left crus, corpus callosum and right parietal lobe, rebounding from right parietal bone, it lodged into the posterior horn of the right ventricle. The original cartridge was a .22 short rim-fire lead bullet, weight 29 grains, velocity of 969 f.s. The deformed bullet as shown in Fig. 100 weighs 27 grains. The patient never regained consciousness and died in five hours from compression due to hemorrhage.

Perforating Fractures.—These fractures are extremely fatal in war. The majority of the cases never live to reach field hospitals.

Otis fixes the mortality of those treated in the hospitals in the Civil War at 80 per cent. Of seventy-three cases only fourteen survived to be discharged and placed upon the pension rolls. It goes without saying that the fatality of perforating fractures of the skull is as great to-day with the use of the present armament when the ball traverses the vital parts of the brain as it was formerly with the old armament. At the battle of Santiago we found that the shots traversing the posterior two-thirds of the skull vertically, obliquely, or transversely

FIG. 99.—Skiagram in case of Pvt. J. S. Powell, Co. "K" 9th Inf., showing a Krag-Jorgensen bullet lodged on the tentorium. Army Med. School collection X-ray Laboratory.

near the base, were uniformly fatal, and that the amount of lesion and fragmentation were proportional to the remaining velocity and energy of the bullet.

The so-called *explosive effects* of the modern military rifle are strikingly exhibited in perforating fracture from proximal shots on the skull. Explosive effects have often been reproduced experimentally on inanimate matter, like containers of tin or sheet

lead, filled with water, starch paste, etc. In the human body the skull with its rigid walls and semifluid contents approaches nearest in point of resistance to the containers of the experimenters and the force which causes the remarkable lesions by the small bullet in certain wounds of the head is the same as that which swells and forces apart the walls of the containers. (See Figs. 69 to 74.)

The power of our present military rifle in the living in producing typical explosive effects is shown in a case of suicide recently reported by Lieut.-Colonel Charles Wilcox, Medical Corps, U. S. Army. The present bullet, as already stated, is jacketed, pointed, length 1.08 inches, 30-caliber, weighing 150 grains, initial velocity 2700 f.s., energy at the muzzle, 2400 foot-pounds. The weapon ranks among the most powerful military rifles in present use.

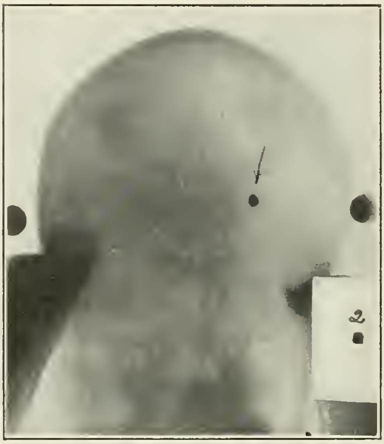


FIG. 100.—1. A .22 cal. bullet lodged in brain as indicated by arrow. 2. Photograph of bullet removed. Army Med. School collection. Lattermann Hospital, X-ray Laboratory.

Patrick Dolan, Co. "K" 27th U. S. Infantry, shot himself November 13, 1911. The muzzle of the piece was probably held in his mouth or near it in a direction from base to vertex of the skull. The extensive destruction of soft parts obliterated all semblance to a wound of entrance or exit. The photographs show extensive destruction. The face above the lower jaw; the entire cerebrum and cranial vault were blown away. "The entire squad-room, especially the ceiling, was stained with blood and fragments of brain." The reporter very properly adds "If this body had been found on a battlefield after an action in which artillery fire had played a part it would undoubtedly be assumed and with good reason that the head had been carried away by either a large projectile or a large fragment of the same." Figs. 100 and 102.

In the case cited, doubtless, the force of the expanding gases, liberated at the time of the escape of the bullet, added to the explosive effects, but aside from the pressure exerted by the gases we know that the energy of the projectile itself as well as that of the secondary missiles, like pieces of bone, dura and partiacles of brain

matter, which became animated with part of the energy of the projectile at the time of impact, assisted materially in the production of destructive effects.

The bone lesion in a transverse shot at the base of the skull at an average battle range is exhibited in Fig. 103, a specimen from the Army Medical Museum, which shows the effects of an experimental

FIG. 101.—Photograph showing side view in case of Patrick Dolan. Army Med. School collection. Ft. Sheridan X-ray Laboratory.

shot in a cadaver by the same ammunition as that noted in the preceding case. The bullet was impressed with the simulated velocity at 900 yards. It key-holed in the head of the barrel of saw-dust which was placed behind the target. In turning the ball struck the inner table of the skull side on, which no doubt added to the size of the wound of exit in the scalp, and helped to fissure and comminute the bony vault as shown in the figure. There was extensive laceration of brain tissue on the exit side, which was no doubt due to the

FIG. 102.—Posterior view of Fig 101.

FIG. 103.—Photograph shows an experimental shot fracture of skull, of cadaver, brain *in situ*, by the pointed bullet .30 cal. Springfield rifle, simulated velocity at 900 yards; wound of entrance over left temporal bone, size and shape of bullet; wouud of exit irregularly round, 1 inch diameter. No. 14180 Pathological Series. Specimen from the A. M. M.

direct transmission of part of the bullet's energy to the brain particles which were themselves shot forth with violence against the bone, thus adding to the destructive effects. The skull as a whole shows more fissuring than is usually seen in a gunshot fracture with the remaining velocity at 900 yards. The subject was past sixty years, and

FIG. 104.—Army Medical Museum collection. No. 10910 pathological series.

no doubt the brittle condition of the bones of the aged figured in the amount of fragmentation. In war the subjects are young men as a rule and the bony lesions are not so marked.

Figure 104 shows the appearance of a postero-anterior injury in the living, near the vault, by the Krag-Jorgensen bullet at close range in the case of a prisoner who attempted to escape from the guard. The bullet was .30 calibers, jacketed; weight 220 grains, ogival-

headed with an initial velocity of 2000 f.s. It is the Krag-Jorgensen bullet which was used by the U. S. Army until 1906.[1] The victim was 90 feet from the rifle when hit. He was running from the guard at the time. The wound of entrance was in the occiput and that of exit in the frontal region as shown in the figure. "After passing through the man's skull the ball penetrated a tree 8 inches in diameter and buried itself in the ground 2 feet. The man lived one hour." The wound of entrance in the skin presented a round opening. . . . .

. . . . The wound of exit in front was larger and more ragged. The integument was carefully dissected off and the bone at the top of the skull found extensively fractured, the parts being here and there connected by fascia. On the calvarium being removed the surface of the dura mater presented a state of intense congestion. To the right of the longitudinal fissure it was torn through for a distance of about 4 inches. . . . . . On removal of the coverings the convolutions of the brain were made prominent by the engorged network of superficial veins. A furrow corresponding to the injury of the dura was ploughed through the right hemisphere in the region of the superior frontal convolution about 1/2 inch deep. The right lateral sinus appeared filled with blood serum, the left was normal. After removal of the brain the cribriform plate exhibited comminuted fracture; one or two slight fissures in the petrous and squamous portions of the temporal bone, otherwise the bone was intact."

The explosive effects would have been more marked had the projectile entered nearer the base and penetrated where the maximum resistance in the skull was located. As it was it did a great deal of damage but it escaped with sufficient remaining energy to penetrate 8 inches into a tree and 2 feet in the ground where it was found undeformed.

While we were testing the comparative difference between the effects of the large and small-caliber bullets in 1893,[2] we shot in the skull of a cadaver with the .45-caliber Springfield rifle. The bullet weighed 500 grains with an I.V. of 1301 f.s. Fig. 105 has a marked resemblance to the preceding. The bullet in this instance entered the frontal bone 2.17 inches above the middle of the right orbit, impressed by the simulated velocity at 250 yards. The bone lesion shows that

[1] The Krag-Jorgensen Rifle. A report of its effects on the skull of the living, etc., by A. C. Girard, M. C., U. S. A., Jour. Amer. Med. Assn., 1895, No. 25.

[2] Report S. G. O., 1893.

the explosive effects of the two bullets are quite similar in the proximal ranges in the dead or living. The deformed .45-caliber bullet which caused the injury is shown in the illustration.

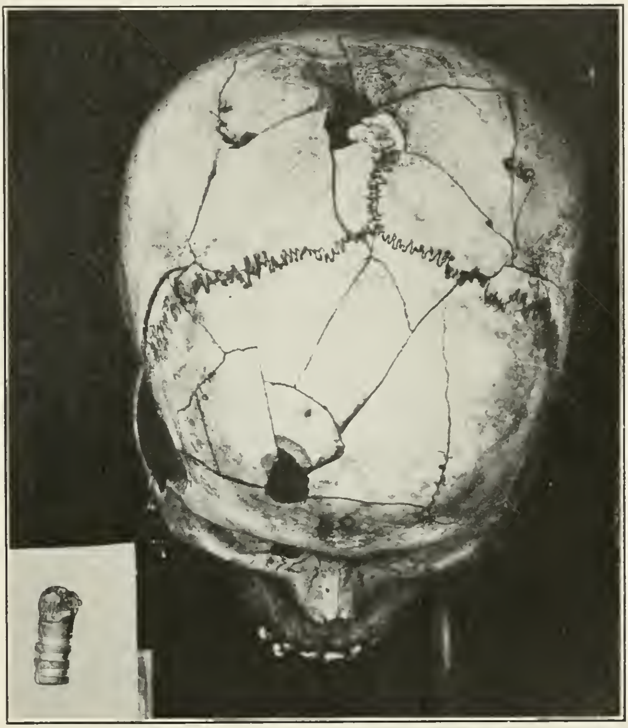


FIG. 105.—Photograph of skull. (1) Lower orifice marks point of entrance of bullet. (2. Upper orifice marks point of exit of bullet. (3) Photo. of bullet left-hand side of figure. No) 10921 A. M. Museum collection.

The following is a familiar example of gunshot injury involving the frontal lobe: B. C. Barker, Pvt. Co. C, 4th Infantry, was shot with a Mauser bullet July 1 at Santiago. The bullet passed through the left temporal region, comminuting the bone extensively, and caused a wound of exit at the left frontal eminence. Loose fragments were removed a few days thereafter when the wound was found to be suppurating. When last seen before discharge there was healing of wound, no cerebral hernia. Mind was clear most of the time, occasional confusion and wandering, March 18, 1912. Mr. Barker is now a $24 per month pensioner. In a letter written by him March 16, 1912,

he states that he is entirely incapacitated for work. Lifting, stooping, overexertion and heat bring on dizzy spells.

Makins, referring to the effects of the reduced-caliber bullet, found vertical and coronal perforations in the frontal region common in the Anglo-Boer War. With lower velocities simple punctured fractures in entering and leaving the skull were noted which, as indicated by the symptoms, were "without extensive lesion of the frontal lobes."

Fig. 106.—A recent photograph of Mr. B. C. Barker, showing the scar and depression of skull over the left frontal region. A. M. School collection.

Stevenson refers to the results in sixty unselected cases of perforating fractures of the skull in the same campaign in which the mortality was 38.3 per cent. As compared to 80 per cent. in the ninety-three cases in the Civil War reported by Otis, the reduction in fatal cases is most marked.

The practice of modern times favors operative interference in nearly all cases of gunshot fracture of the skull, and to this practice we attribute the greater ratio of recoveries. At the same time that

FIG. 107.—Skiagram shows bullet of the .38 cal. Colt's revolver lodged under the skin 2.25 cm. above the posterior occipital protuberance. Sgt. V. held the muzzle of the revolver near his head and fired with suicidal intent. The bullet entered 5 cm. above bregma near center of frontal bone. There was fracture of the cranium along the superior longitudinal sinus from wound of entrance to point of lodgment of ball. A fracture extended downward into the left parietal to the middle of the left temporal bone. Another fracture extended to the right, to upper part of right temporal bone while other fractures were present as shown in skiagrams. Superior longitudinal sinus and upper part right cerebral hemisphere badly lacerated. Patient lived but 25 minutes after he was shot. The bullet had not sufficient energy to perforate the scalp. Army Med. School collection. X-ray Laboratory. Presidio General Hospital.

FIG. 108.—Skiagram showing side view of Fig. 107. Army Med. School collection.

lives are saved in larger numbers now, there are sequelæ and complications among those who survive that are most distressing

In connection with the subject of perforating wounds by the military rifle bullet, it is interesting to note that the same character of lesion will occur henceforth from pistol bullets, because automatic pistols which fire steel-jacketed projectiles are becoming part of the armament of the nations in lieu of revolvers which employ lead bullets.

FIG. 109.—Skiagram showing perforating fracture of head by Colt's new service revolver .45 cal. lead bullet at close range in cadaver, brain *in situ*. Ball flattened, lost its penetration and then lodged. Note particles of lead in track of bullet. Army Medical School collection.

Hitherto the greater number of gunshot injuries of the cranium from revolvers in both civil and military practice resulted in *penetrating* fractures with lodged balls. This was due to comparatively low velocities, and the great tendency of the lead bullets to deform on impact against the hard skull. Even in the proximal ranges the bullet of the .45 and .38-caliber new service Colts revolvers, two of the most

effective weapons of their type, and which were recently discarded by our army, failed to perforate the skull in the majority of cases. (See Figs. 107, 108, 109.)

Fig. 110.—Photograph of gun-shot fracture of cranium in cadaver with brain *in situ* by the Luger automatic pistol bullet, cal. 7 65 mm. at 37 1/2 yards, with velocity of 1258 f.s. Bullet entered left orbit and emerged above and behind right auditory meatus fracturing left malar, orbital, surface superior maxillary, ethmoid, body and great wing of sphenoid, vomer; separated the right malar, fracturing frontal over orbit, right parietal, petrous squamous and mastoid portions of right temporal, left parietal and left occipital bones. Philadelphia Polyclinic, service of Dr. A. Hewson.

Jacketing the bullet of the automatic weapons, and the use of smokeless powder, have added to the penetration and velocity of the

new arm to such an extent that its bullets will seldom deform, they will lodge less often in the tissues, including the skull. The wounds of the cranial region will be of the *perforating* kind and the lesions will more nearly approach those produced by the military rifle.

Fig. 110 shows the amount of fissuring which results from the energy of these powerful pistols. The amount of fragmentation is doubtless increased by the fact that the shorter bullet is unstable and travels at a tangent to its line of flight on meeting slight resistance. For ballistics of pistols and revolvers, see pages 70–71.

Remote Effects of Head Wounds.—The disabling consequences of gunshot injuries of the head are very common. Longmore in his wide experience states that but few cases of head injuries from gunshot, be they contusions or fracture, fail to show evidence of cerebral disturbance.

Cicatrices of the scalp are occasionally painful enough to require excision. After either severe injury or concussion to the brain there are annoying symptoms such as headache, dizziness, irritability, etc., which are noticed in convalescence and more particularly when the patient resumes his vocation. In many cases the symptoms persist and in some they become worse. Paralytic symptoms are worse at first and tend to disappear wholly or in part with time. Symptoms like the latter no doubt owe their presence to vibratory disturbances and small parenchymatous hemorrhages which tend to disappear with the process of repair, and they are at their worst during this time. In soldiers they are prone to recur when on duty in hot climates. They are aggravated by the use of alcohol. Physical and mental endurance are often undertaken with fatigue; patients are disturbed by trifles and sensitive to sensory stimuli. The memory may be impaired, patients forget names; they become forgetful through lack of attention. Changes in character may be seen; those who were formerly of a cheerful disposition become eccentric, irascible, moody, and fault-finding. Epilepsy is common, and insanity has been noted. Destruction of specialized areas of the cortex like the speech center are apt to remain permanent.

The complications of gunshot fracture of the skull are concussion, compression and hemorrhage, with meningitis, encephalitis, hernia cerebri and brain abscess as sequelæ.

Concussion, Compression and Hemorrhage.—The symptoms of concussion and compression are difficult to differentiate in the beginning unless depressed bone is apparent. They are usually accom-

panied by unconsciousness and shock. It should be remembered that concussion per se is rare in gunshot of the skull, while compression from depressed bone or hemorrhage either above or below the dura is common. Concussion which results from contusion, guttering or the minor injuries to the skull is apt to be transient. In penetrating or perforating wounds, the symptoms of brain injury accompany those of compression if the latter be present. The symptoms of compression from depressed bone occur immediately after the receipt of the injury, while the symptoms from hemorrhage are more apt to come gradually. Hemorrhage between the skull and dura may be produced by contusion or fracture. The middle meningeal or some of its branches are usually implicated especially if the bleeding is severe.

Meningitis, encephalitis, hernia cerebri and brain abscess are grave symptoms because nearly all fatal cases of gunshot injury of the head in the later stages die from one or more of these complications. It is needless to state that they all arise from primary infection which is prone to occur in head wounds.

Hernia cerebri is one of the common and very fatal complications of gunshot fracture of the cranium. It results from rupture of the dura in fractures of the skull by the penetration of missiles or depressed fragments of bone. It may be primary or secondary. In the primary form there is usually a larger opening through which the brain matter escapes beyond its normal level, at the time of the injury. It is most generally the result of pressure exerted by internal hemorrhage. In recent wars it has been noted as an accompaniment of cranial fracture attended with explosive effects from proximal shots by the military rifle. The secondary form results from intracranial pressure which may be exerted by an abscess or by the products of inflammation as in meningitis and encephalitis. Primary cerebral hernia is nearly always fatal. Otis reports fifty-five cases of secondary cerebral hernia with a mortality of 80 per cent. Stevenson refers to twelve cases in the Anglo-Boer War with a mortality of 41.9 per cent. In the Russo-Japanese War Lynch reports upon the frequency and fatality of cerebral hernias in the Japanese hospitals. He attributes their frequency to the large openings made in the skulls by the Russian surgeons. The protruded mass is usually covered by granulating tissue.

Treatment of cerebral hernia consists in protecting the ulcerated surface by clean dry dressings applied with moderate pressure. The parts should be washed daily with mild antiseptic solutions and gently

dried before reapplication of the dressing. Absolute alcohol is recommended, to be painted on the growth daily for its cleansing and dehydrating effects. Excision and cauterization have their dangers but they have been attended with success. Skin transplanting and osteoplastic repair have given good results in suitable cases. Gangrene and spontaneous separation sometimes result in cure. The stump is covered by granulations and finally healed by connective-tissue formation.

Abscess of the brain as a complication of gunshot fracture of the cranium rarely appears earlier than the tenth day, but more often during the second and third weeks. The symptoms are nearly always insidious in their onset. They consist of slight rise of temperature, headache, chill, nausea and vomiting, drowsiness. Jacksonian epilepsy appears in some cases, also irritability of temper. Choked disc is a fairly constant, and slow pulse is a significant symptom.

When abscess is suspected exploration with a hypodermic needle or small trocar should be practised at once, and when pus is found it should be evacuated, and the abscess cavity irrigated and drained. The abscess will usually be found in the injured area but not necessarily so. In any event it should be sought for in the area indicated by the localizing symptoms.

Treatment of gunshot fractures of the cranium consists in prompt operative interference in every case that offers any hope of recovery. With our present knowledge we know that the expectant attitude employed in the days of our Civil War was responsible for a large number of deaths. It was in order then to await symptoms and then to operate. If we pursued the same practice to-day our results would be but little better notwithstanding the aid which we receive from antiseptic treatment. A gunshot fracture of the cranium is in the nature of a punctured wound and it is infected primarily by the ball and skin of the scalp in every case. Cases in which the ball has traversed the brain deeply near the base, and those cases exhibiting long bullet tracks vertically or transversely except in the frontal lobes give but little promise of relief by operation. The same is true of gunshot in any region which bears evidence of explosive effects from proximal shots. In the latter the brain and bone lesions are marked by fissures, lacerations, and brain pulp is present beyond the bullet's track. Spiculæ of bone and often particles of metal are driven into the brain substance, causing dangerous wounds in themselves.

The time for operation should be immediately after the receipt of

the injury, because delay means sepsis. Of the cases demanding attention at a dressing station, the head cases should be among the first selected. Since infection is about the only danger to be feared, the greatest precaution should be taken to prevent infection from the beginning. To that end the scalp should first be shaved and cleansed. In the emergent conditions attending battle there is scarcity of water, as a rule. Fortunately tincture of iodine or Lugol's solution is a ready and efficient substitute in the field and one or the other of these should be applied in 50 per cent. strength to the whole scalp as soon as it has been shaved or closely clipped. A flap should next be raised at the wound of entrance with its convexity directed in the best way to promote drainage, the bullet opening forming the center of the raised flap. If the opening in the skull is not sufficiently large to permit thorough exploration space can be gained by the use of the rongeur. Loose fragments under the scalp and those driven in and about the entrance wound should be sought for and removed. It is well to explore the channel in the brain for 2 inches or more for lodged pieces of bone, the bullet, or pieces thereof. All fragments and foreign bodies having been removed, the disintegrated brain pulp and blood clots are carefully washed away. The scalp wound is then closed by suture without drainage. The latter can be secured most readily at any subsequent time if necessary. The surgeons in recent campaigns insist upon the value of primary union, an outcome which so readily insures against the occurrence of complications of a fatal or annoying nature. The wound of exit, if it shows marked lesion, should be treated likewise. The less severe cases seldom requires more than cleaning and a primary dressing. Gutter fractures wherein the floor of the gutter is formed by the fragmented inner table should be freed of fragments and the edges of the two tables made smooth by rongeur-forceps. Depressed fractures without perforation should be explored and the depressed fragments replaced. Fragments of the inner table which make pressure on the dura or brain should be removed entirely It is a safe rule to explore all gunshot wounds of the cranium whether fracture is apparent or not. In cases of doubt no harm can come from removing a half-inch crown of skull near the point of impact, for the purpose of exploration. Such a practice is prompted by the number of cases which are related in all works on military surgery of apparently trivial contusions, which later terminated disastrously from injury to the brain or its membranes. In this connection we should remember that gunshot wounds differ from wounds by other offending bodies in that

the missile is usually animated by an amount of energy which is often dissipated in the produoction of fractures that are not always apparent to the sense of touch or sight.

The treatment above indicated was faithfully followed by the British surgeons in the Anglo-Boer War. The army was accompanied by celebrated clinicians who carried out the policy of early, thorough and careful exploratory work in all head cases. The consequence was that their average mortality in sixty-three gutter, thirteen penetrating and sixty perforating fractures of the cranium was only 29.1 per cent. The boldness and forethought of the British surgeons is well worthy of emulation. No doubt their example will be a factor in the reduction of the fatality of head wounds in the wars of the future. The same plan of treatment was observed in the Manchurian campaign, according to Dr. V. Oettingen.[1] The value of early operation to ward off abscess, meningitis, etc., was carried out promptly. He introduced his finger covered with a rubber glove deep into the wounds to cleanse them of all bone and metallic fragments.

Removal of Lodged Missiles.—Attempt to remove foreign bodies like bullets or pieces of shell from the brain are to be discouraged unless the indications are prompted by easy access, as shown by the Röntgen-ray plate, or by very annoying symptoms. Past experience discourages the practice of prolonged search for balls, which more often ends in failure and the infliction of wounds more dangerous than the presence of the foreign body itself. The inconveniences of a ball buried in the brain are not sufficient to warrant the risks of operation, as a rule. Fortunately lodged missiles from the present armament will rarely occur because of the superior penetration of the jacketed bullets. Furthermore, the reduction in weight of military rifle bullets from 500 to 150 grains will be attended with fewer and less severe symptoms from lodged missiles in the brain than have been noted heretofore.

(2) **Gunshot Wounds of the Face.**—Gunshot wounds of the face have their chief interest in the disfigurement which follows injuries by shell fragments and large-caliber rifle bullets. The mortality of face wounds has never been high. Secondary hemorrhage and suppuration extending to the meninges from necrosis of bone and lodged balls embedded in the spongy bones of the nasal and supramaxillary regions were the chief causes of death in preantiseptic times. Among 2276 gunshot injuries entered on the U. S. Army registers for 1899

[1] Münch. Med. Wochens, 1906, No. 7, p. 218.

from all kinds of missiles there were twenty-seven fractures of the bones of the face with two deaths.

The character of wounds from shell fragments, shrapnel and large-caliber rifle bullets is the same to-day as formerly and in spite of our best endeavor deaths still occur from inflammation extending to the meninges and brain. The absence of disfigurement from shots by the modern military rifle bullet beyond the proximal ranges is one of the striking evidences of the beneficence which comes from the use of the new arm.

Wounds of the Ear.—Wounds through the pinna are slit-like and heal rapidly. Shots in and near the external auditory meatus are apt to end in paralysis of the seventh nerve and deafness as a result of vibratory concussion.

Fig. 111.—Skiagram shows .22 cal. bullet lodged in orbit. Army Med. School collection. From Lettermann Genl. Hospital.

Wounds of the Orbit.—Are common and serious to vision. Transverse shots are the most serious as they are prone to injure both eyes. Aside from direct traumatism to the globe or optic nerve itself, blindness has frequently been observed in recent wars from vibratory impulses on impact, causing minute hemorrhages from rupture of choroidal vessels. In such cases unless vision returns soon after the receipt of the injury the prognosis is bad. In the case of an officer who received a transverse shot from a Mauser bullet at Santiago just beneath the orbits, it is at present impossible to detect, on careful inspection, the scars which mark the location of the wounds of entrance and exit. The author had this officer for a patient a few days after he was wounded, and he has served with him for two years since, on his official staff, but he cannot recall any visible disfigurement from the effects of the wounds. The left eye was injured at the time, causing total blindness, so that it was subsequently enucleated, and the vision

in the right eye remains slightly impaired as a result of vibratory concussion.

Fig. 111 shows the dangers of the .22-caliber target practice ammunition so much used in this country for sporting purposes, and also used in our army for gallery practice. Private Frank Piaski, Co. H, 30th Infantry, was shot while in target pit March 28, 1910, with a .22-caliber (short commercial) cartridge, the bullet entering the right eye just above the inner canthus, resulting in total blindness in the injured eye. As seen in the figure the ball lies lodged in the back part of the orbit and its path is marked by a stream of lead particles. The latter would indicate that the ball was deformed on being deflected by the frontal bone at the lower and internal end of the superciliary ridge where the bone is thick, and, having lost its momentum, it lodged as shown in the skiagram.

Wounds of the Nose.—The cartilages of the nose like those of the pinna of the ear suffer slit-like wounds that heal readily. In the case of an officer at the battle of Santiago, whose case has already been referred to under the subject of multiple wounds, the ball perforated the soft parts of the cheek, then passed through the cartilages of the nose in and out in a transverse direction. The wounds were trifling in their nature and he preferred to return to the line rather than suffer shipment home with other wounded. Wounds of the nasal fossæ have been known to destroy the sense of smell, most likely as a result of vibratory impulse.

Wounds of the Malar Bones.—The malar bones are the most resistant bones of the upper part of the face and shots received in the explosive zone are apt to be attended with fissuring and displacement of bone fragments, causing lacerations which in turn augment the tendency to inflammation. In the mid and remote ranges the bone lesion takes the nature of a perforation.

Wounds of the Upper Jaw.—Are apt to include the antrum, buccal cavity, alveolar process and teeth. The latter are often displaced with violence, causing lacerations which are painful and heal slowly. Lt. W. S. W., 9th Cavalry, was shot by a Mauser bullet at Santiago July 1. The bullet entered the lower lip near the right angle of the mouth, causing loss of four teeth in the lower jaw and fracture of the four upper incisors and right upper molar. It was here deflected and passed under the inferior maxilla and lodged in the left sterno-cleido-mastoid. There were lacerations in the mouth and tongue causing much pain and discomfort with attendant in-

flammation which extended down the neck. The bullet was removed from the substance of the sterno-cleido-mastoid about its middle at Soldiers Home Hospital, D. C., in October, 1898.

Balls penetrating the buccal cavity often groove or perforate the tongue, but they seldom lodge in its substance. Figs. 112 and 113 show an improvised Filipino bullet from a Mauser rifle which we removed from the base of the tongue and Fig. 114 shows a jacketed bullet lodged in the antrum.

Wounds of the Lower Jaw.—When the mandible is struck by a high-velocity bullet, its compact substance splinters readily, causing

Fig. 112

Fig. 113

Fig. 112.—Radiograph of G. W. G., showing lead slug lodged in base of tongue. The ball entered behind the left ear. Radiograph taken fourteen months after injury. Remote effects: Left hemiparalysis of tongue also loss of taste on left side; loss of hearing in left ear; left optic neuritis; partial anchylosis of lower jaw and painful deglutition. The bullet was removed Oct. 4, 1900. The painful deglutition was completely relieved. Photo of bullet is shown in Fig. 113. Army Med. School collection. U. S. Soldiers Home X-ray Laboratory. Dr. A. B. Herrick, X-rayist.

corresponding damage to soft parts. The traumatism is greater still when teeth are displaced from the alveolar process. In the mid and remote ranges the small jacketed bullet is apt to gutter or perforate the bone with little splintering. Fractures of the upper part of the ascending ramus and neck of the condyle are often attended with comminution and are apt to cause anchylosis unless properly explored at the time.

Treatment.—In wounds of the orbit with brain injury, if the bullet has passed from the orbit to the brain it is preferable to enucleate the eye at once and remove such spiculæ of bone as may be necessary from the wound of entrance in the roof of the orbit. In all other cases with concurrent brain injury in which the globe has been de-

stroyed it is preferable to defer enucleation until after closure of the wound in the orbital roof. In cases of lodged balls in and about the orbit the missile should be removed at once and enucleation practised

Fig. 114.—Pvt. Cornelius L. E. Co. "K," 1st Neb. Vol. shot in face by a 45. cal. brass-jacketed Remington bullet Feb. 5, 1899 at Block-house No. 7, P. I. Bullet entered over left eye-brow 1/2 inch from inner canthus and lodged in right antrum of Highmore. Removed by Maj. A. C. Girard, M. C., U. S. A., at Lettermann Genl. Hospital, Aug. 16, 1899. Remote effects: Partial deafness left ear: total blindness right eye from choroiditis and optic atrophy. Anchylosis of jaw, but slight separation of teeth. Lettermann Hospital X-ray Laboratory.

at the time if necessary. Fracture of the upper jaw seldom needs active treatment except to remove spiculæ of bone, teeth, and lodged missiles when localized by the X-ray or otherwise. In the case of

the mandible when the buccal cavity is involved, prompt active treatment is necessary to remove all pieces of loose bone which may favor suppuration and necrosis later. Prompt removal of comminuted bone should also be practised in fractures of the ramus to forestall anchylosis of the lower jaw, which is so apt to occur with the extensive comminution and resulting callus. Fixation should be practised by a four-tailed chin bandage which is about all that is obtainable in the field. Later the more permanent and effective

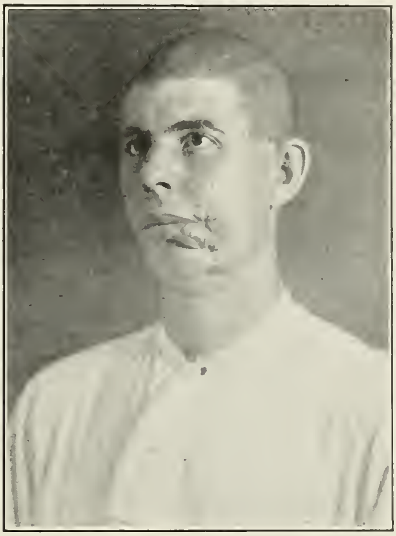


Fig. 115.—This soldier shot himself at Jolo, P. I., in 1907, with Springfield rifle cal. .30 more by accident than intent. While in the company of several of his comrades one evening, he desired them to believe that he was about to commit suicide and placed the muzzle of his weapon under his chin saying, "here goes boys," at the same time pulling the trigger. He admitted afterward that he intended to throw his head back far enough to avoid the ball, but failed to do so, receiving a wound which shattered the inferior maxillary bone and lacerated the surrounding tissues. The case illustrates how much disfigurement can occur from reduced caliber rifle bullets at proximal ranges. Army Medical School collection.

methods of fixation should be employed. Wounds of the lips, cheeks, and tongue usually heal rapidly. Antiseptic mouth washes should be employed in wounds implicating the tongue, buccal and nasal cavities.

(3) **Gunshot Wounds of the Neck.**—Shot wounds of the neck exclusive of injury to cervical vertebræ are not excessively fatal. Of 4114 known results of this class of cases reported in the surgical vol-

umes of the Civil War, Otis gives a mortality of 15 per cent. The sub-joined table[1] from the same source, aside from giving the mortality for that time, is interesting as it gives the ratio of hits in some of the important anatomical structures for a large number of neck wounds.

TABLE OF 4895 CASES OF GUNSHOT WOUNDS OF THE NECK WITHOUT KNOWN INJURY TO THE CERVICAL VERTEBRÆ (OTIS)

Character of wound	Cases	Died	Dis-charged	Duty	Un-known
Gunshot Wounds of the Neck	4789	570	1056	2394	769
Gunshot Wounds of the Neck, injuring Trachea	41	21	11	8	1
Gunshot Wounds of the Neck, injuring Larynx	30	10	8	2	10
Gunshot Wounds of the Neck, injuring Pharynx	13	7	2	3	1
Gunshot Wounds of the Neck, injuring Esophagus	10	6	2	2	......
Gunshot Wounds of the Neck, injuring Tra. & Lar.	4	......	1	3	......
Gunshot Wounds of the Neck, injuring Tra. & Phar.	2	......	2	......	......
Gunshot Wounds of the Neck, injuring Tra. & Esoph.	2	2	......	......	......
Gunshot Wounds of the Neck, injuring Lar. & Esoph	1	......	1	......	......
Gunshot Wounds of the Neck, injuring Phar. & Esoph.	1	......	......	1	......
Gunshot Wounds of the Neck, injuring Phar. & Lary.	2	2	......	......	......
Aggregates	4895	618	1083	2413	781

The high mortality in those wounds involving the trachea, larynx, pharynx and esophagus alone or otherwise is no doubt significant of the effects of the armament and mode of treatment at that time. The large number of cases, viz., 4789 of gunshot wounds of the neck, with an aggregate mortality of 14.1, shows even for the old armament how curiously the large vessels and spinal cord escape injury *in this rather limited target area*. A line drawn transversely at the root of the average size neck in life measures about 4 1/2 inches, and 4 inches when the measurement is taken transversely across the neck under the extended chin. The antero-posterior and oblique diameters at about the same levels exceed these measurements by about 1/2 inch. In the middle of this space the spinal column runs longitudinally and it measures on the skeleton approximately an average of 2 inches transversely, while the spinal canal proper measures about 3/4 inch in its antero-posterior diameter.

The failure to note vertebral lesions in this array of neck wounds is due no doubt to their entire absence. Such cases were very probably numbered among the dead from direct injury to the cord or as a result of vibratory concussion in bone injuries so near the vital centers. The record makes note of primary and secondary hemorrhage in a

certain proportion of cases, but the principal feature of the neck wound for that day was the striking manner in which the missiles, like round and conoidal lead balls, eluded the great vessels while from every external appearance they traversed their course. It was then believed, and very properly, that the vessels lying loose and movable in the tissues were pushed aside by the slowly moving obtuse bodies. In those cases where the vessels were severed, the larger caliber of those days caused so much laceration of the large vessels that the result was immediate death from primary hemorrhage.

The beneficence which comes from reduction in the caliber of the military rifle is very evident from the results in neck wounds in recent wars. This was noticeable to us at Santiago in cases of injury to the air passages and the great vessels alike. The larynx, trachea, and great vessels were all in turn perforated without fatal outcome. The death rate of 133 neck cases who lived to reach hospital care in the Spanish-American War was 18 per cent. Two of the fatal cases were operated upon for subclavian aneurysm. Although the official reports from the Anglo-Boer and Russo-Japanese Wars are not yet available, we have reason to believe from the published reports of the observers in these wars that the results in the Spanish American War are a fair index of the mortality to be expected from shot wounds of the neck under present conditions.

We noticed a number of cases, after the battle of Santiago, of incredible escape of important structures in the neck and our observations have been confirmed repeatedly by observers in recent wars.

In the case of Pvt. O. C. Buck, Co. F, 2nd Infantry, who was shot by a sharp-shooter July 11, a Spanish Mauser bullet passed transversely through the neck. Profuse bleeding from the throat followed immediately, but this soon subsided and ceased entirely during the day. No other symptoms were present in the subsequent history of the case except slight stiffness of the neck and pain on movement. The bullet entered on the left side 2 inches below the mastoid process, making a small circular wound, and passed through the sterno-cleido-mastoid muscle; the wound of exit was on the opposite side of the neck, on the same level and 1/2 inch nearer the spine. There were no symptoms of a subsequent nature referable to the principal nerves and large vessels of the neck, and yet it is difficult to conceive how the projectile made its passage through the neck without involving these important structures.

The spinal column and cord made a marvelous escape in the case

of Pvt. Charles F. F., Company C, 4th Infantry, who was wounded July 1, while firing in the prone position. The bullet, a Spanish Mauser, entered the left side of the neck opposite the fifth cervical spine mid-way between it and the posterior border of the sterno-cleido-mastoid. Ranging downward and to the right it made its exit opposite the seventh dorsal spine half-way between it and the vertebral border of the scapula. The only symptom complained of was pain in the shoulders on moving the arms. No symptoms of a paralytic or other nature referable to cord lesion were ever present, although he was shot when 100 yards from the enemy.

Makins mentions the occurrence of "several cases in which the bullet traversed the neck behind the pharynx and esophagus without injury to either viscus, and the escape of the main vessels and nerves was equally striking." Follenfant in Manchuria states that his comrade, Prince Murat, received a wound across the neck which disabled him very much for six days. He was back on the line at the end of a few weeks. The jacketed bullet entered the right side of the neck under the angle of the lower jaw and emerged on the left side behind the larynx. There was difficulty in deglutition for five days. No after-effects were present save an anesthetic patch the size of a 5-franc piece on the right side of the neck.

Complications of Gunshot Wounds of the Neck.—Wounds of the larynx and trachea are sometimes complicated with septic pneumonia; injury to the great vessels may cause hemorrhage or traumatic aneurysm, while wounds of the esophagus are prone to infection. Infection in any wound of the neck, unless carefully managed, is apt to lead to deep-seated inflammation with suppuration.

Wounds of the Great Vessels or Their Branches.—Aneurysm which arises from wounds of neck vessels will be referred to under "Injury to Blood-vessels,"

Hemorrhage attending laceration of vessels of the neck when alarming and continuous should be treated by ligation of the vessel above and below the point of injury. In large wounds as by shell fragments or large lead bullets, patients seldom live long enough to reach surgical aid. Smaller missiles like the steel-clad bullets of the present-day military rifle often cause wounds in which the flow of blood is not constant both from the small channel made by the projectile, and from obstruction of the flow which results from a change in the position of the overlying layers of muscle, fascia, etc. A recurrence of the hemorrhage after a temporary spurt of blood should

be an indication for cutting down upon the bleeding vessel. The sooner this is done, the better will be the prognosis. Temporizing in such cases leads to the disturbance of anatomical relations from the distention which attends the formation of diffuse aneurysm. In our Civil War the surgeons were wont to use pressure and styptics. Again, instead of cutting down upon the vessels at the point of injury they often resorted to the faulty practice of tying the common carotid to control hemorrhage from some of its branches. Otis' characterization of this method is as applicable to-day as it was then. To him these surgeons were only "associating their names with the necrology of ligations." He makes note of a total of seventy-six ligations of the common carotid for gunshot about the face and neck with a mortality of 78.6 per cent. This practice was not attended with very much better results in the Franco-Russian War of 1870–71, where the registered mortality in like cases was 68.7, in the German Army. The surgical practice of to-day is to cut down and tie the bleeding points in the wound wherever this is possible. When, however, the wound in the neck is above the bifurcation of the common carotid, in the parotid region, there is usually much difficulty in attempting to expose the bleeding vessel. It is then difficult to ascertain which of the divisions of the main trunk is causing the hemorrhage. In such a case operators follow the practice first recommended by Richet *of exposing* the origin of the two carotids, then successively to compress the vessels and finally to tie the one that seems to control the hemorrhage. If the compression of the one or the other does not entirely arrest the hemorrhage, he then advises ligation of both the external and internal carotids. As an additional precautionary measure to prevent a recurrence of the hemorrhage, Delorme[1] would enlarge the skin incision and pack the wound with antiseptic tampons. Follenfant[2] states that Bornhaupt, contrary to the usual practice, tied the common carotid twice successfully for hemorrhage in the late Russo-Japanese War.

Wounds of the Jugular Veins.—Wounds of the external jugular is of no moment in our day, though Otis records some cases of death from gunshot of this vessel in our great Civil War. Ligation of both ends of the vessel under proper antiseptic precautions is the treatment now employed. Wounds of the internal jugular have a high mortality. Large veins are not as resistant as the large arteries. they are

[1] Delorme E, Traite de Chirurgie de Guerre.

[2] Op. cit.

not pushed aside as readily by slowly moving projectiles and it is more than likely that the mortality on the field from primary hemorrhage is frequent from uncontrolable venous hemorrhage. Otis records fifteen cases of wounds to the internal jugular with fourteen deaths. Eight of the deaths are ascribed to hemorrhage, five not stated, and one from typhoid pneumonia. Of the cases of gunshot wound of the internal jugular collected by Gross the fatality was 12.5 per cent. from primary hemorrhage; 62.5 per cent. from secondary hemorrhage; 25 per cent. from pyemia. These statistics are of much value since they point to causes of death in 87.5 per cent. of the cases, which under modern methods of treatment are largely preventable. Doubtless the mortality of 12.5 per cent. from primary hemorrhage could be much reduced by ligation of the vein, which is now done with perfect safety. Injury to the jugulars and other large veins by the modern rifle bullet, which are accessible to operative interference when seen in time, will be especially amenable to surgical relief in the majority of cases. Where the vein has been hit at a tangent, application of fine sutures to the margins of the wound in the vessel is one of the recognized procedures. If the wound is very small it can be brought together by a hemostat which can be left in situ for a few days. Where the vessel has been perforated by the projectile, destroying the greater part of its lumen, the procedure is the same as that followed in the case of an injured artery, viz., ligation of the vessel above and below the point of injury.

Wounds of the Nerves of the Neck.—All the nerves of the neck including the sympathetic are subject to injury by gunshot. Unlike injury to nerves of other regions there is little that can be done in the way of surgical relief for nerve injuries in this locality.

The German reports for the war of 1870–71 places the frequency of nerve injuries as 1 to 12 of all neck wounds by gunshots. These injuries are often followed by interesting clinical signs. Injury to the seventh nerve, which often occurs in wounds about the parotid, is invariably followed by complete or partial facial paralysis. Wound of the recurrent laryngeal will cause paralysis of the muscles of phonation on the corresponding side with difficulty in speech; lesion of the spinal accessory by paralysis of the mastoid and trapezius muscles; of the phrenic by paralysis of the diaphragm on the corresponding side, with hiccough, dyspnea and a sensation of constriction around the body. Of the foregoing injuries wounds of the phrenic are the most serious.

Wounds of the pneumogastric by gunshot are attended with an interesting and curious clinical history. By reason of the nerve's intimate relation to the large vessels the latter are nearly always implicated, but in some rare instances the nerve alone has been injured, and the symptoms of injury to it have also been noted where the primary hemorrhage of the vessels has been successfully arrested. The pneumogastric is often implicated in neck injuries, by (a) direct traumatism, (b) by pressure in cases of aneurysm and (c) by the vibratory force of high-power military rifles of the present day. Injury to this important nerve is followed by difficulties of deglutition, phonation and respiration; irregularity and acceleration of the heart beats, and later by pneumonia which is sometimes a cause of death. Makins states that the pneumogastric was often implicated in gunshot wounds of the neck in the South African War. He never observed an uncomplicated case. He is of the opinion that injury to the pneumogastric was a frequent cause of death on the field among those hit in the neck. The staff of A Civilian War Hospital reports a case as follows: "A private was shot through the right orbit at Magersfontein, the bullet traversing the jaw-bone and palate, and emerging through the left side of the neck just at the back of the thyroid cartilage. There was a complete paralysis of the vocal cord, followed by atrophy of the muscles, which could only have been caused by a wound of the pneumogastric nerve, but the patient had no other symptoms which could be attributed to such an injury, and made a good recovery."

Wounds of the neck high up are apt to involve the hypoglossal as well as the pneumogastric. Hirsch[1] reports a case in which the ball lodged opposite the fourth cervical vertebra as shown by the skiagram. The hypoglossal involvement was shown by atrophy of one-half of the tongue, and the pneumogastric injury caused paralysis of the left vocal cord and a continued high pulse, 108.

The pressure symptoms of vagus involvement will be more frequent with the use of the new military rifle, since aneurysm is now more often noted after wounds of the vessels by the small-caliber bullet.

Roswell Park and Makins[2] have shown that the vagus can be cut in operative wounds, and immediately sutured, with incomplete temporary loss of function.

Wounds of the Cervical Sympathetic.—From the intimate anatomi-

[1] Hirsch, Traumatic Injury of the Pneumogastric Nerve, etc., N. Y. Med. J., Vol. LXVI.

[2] London Lancet, May 16, 1896.

cal relation of the cervical sympathetic to the great vessels, the pneumogastric, the cord, air passages, and esophagus, uncomplicated injury to the nerve is seldom seen. In those cases of vessel injury in which recovery has taken place, the characteristic symptoms of cervical sympathetic injury have been noted. The symptoms which appear only upon complete division of the nerve are as follows: (a) Narrowing of the palpebral fissure, (b) sinking in of the eye-ball, (c) contracted pupil, (d) loss of the cilio-spinal reflex, (e) redness and dryness of the skin of the corresponding side of the face. In partial injury to the nerve only some of the foregoing symptoms appear. Reddening of the cheek is one of the symptoms rarely seen. Excessive flow of tears sometimes occurs and it generally proves to be the most annoying symptom. In a certain proportion of cases the symptoms are permanent. Larrey and Weir Mitchell have reported very interesting cases of wounds of the cervical sympathetic in war. Stevenson states that Col. Holt has reported several cases from the Boer War, in which the three most prominent symptoms were "increase of the sweating, myosis, and pseudoptosis (narrowing of the palpebral fissures) on the side of the injury." Holt adds that "marked cardiac rhythmic disturbance and subconjunctival hemorrhage were ascribed to injury of this nerve."

The staff of A Civilian War Hospital notes the following case in the same war: "A private was shot through the right side of the neck, the bullet entering at the middle of the left cheek, and pass ng out 1 1/2 inches to the right of the spinous process of the seventh cervical vertebra. The left eye-ball showed the typical retraction of the globe within the orbit, the diminished palpebral fissure, and the paralysis of the dilator muscle of the iris characteristic of paralysis of the sympathetic nerve."

Wounds of the Brachial Plexus.—These are among the more common nerve injuries of the neck. They are often followed by annoying symptoms of irritation in the way of hyperesthesia or pain. The following case of brachial nerve injury occurred at the battle of Santiago. The injury is typical of the hairbreadth escapes which we sometimes observe with the use of the new armament.

Captain C. W. T., 9th U. S. Cavalry, was shot during a plunging fire July 2, at about 300 yards, while locating the enemy and estimating the range for his men who were lying down. The bullet, a Mauser, entered the left side of the neck on about the level of the upper border of the thyroid cartilage and just internal to the sterno-cleido-mastoid. The bullet's course was downward, backward and obliquely to the right, making its escape from the body 1 inch to the right of the spine

of the seventh cervical vertebra. He fell heavily to the ground and a sergeant who was near thought him dead. He remained unconscious for a few minutes only. He was admitted to the Reserve Divisional Hospital on the third of July, complaining of pain in the distribution of the left median nerve; the neck and left arm were swollen and stiff. The author again examined this officer in December, and off and on for four years thereafter. He was never free from hyperesthesia, formication, numbness, and neuralgic pains of the left arm and hand. The grip of the left hand was about half the power of the right. Judging from the course of the bullet and the persistency with which the symptoms of irritation continued, the projectile more than likely perforated the transverse processes of the fifth and sixth cervical vertebræ, injuring the corresponding cervical nerves, and passing between the spines of the sixth and seventh vertebræ it emerged an inch to the right of the latter. The force of impact which caused the officer to drop so lifeless when shot would indicate that the spinal cord had received a momentary shock from the transmission of the bullet's energy at high velocity. (Fig. 116.)

Fig. 116.—Photograph of cadaver showing course of bullet in case of Capt. C. A. T., 9th U. S. Cavalry.

Wounds of the Air Passages.—Wounds of the larynx and trachea by the old armament were not commonly seen in military hospitals. The proximity of the great vessels and spinal cord made it difficult for a bullet of large caliber to traverse the air passages without causing injury of a fatal kind to either the vessels, the cord or both. Chenu gives but one example of cure from gunshot of the larynx in the Crimean War, and that was complicated by a fistule. Otis' table referred to shows that the air passages of the neck were included in but seventy-seven of 4895 gunshot wounds, or 1.7 per cent. for all neck wounds treated. The mortality of tracheal and laryngeal wounds treated was practically the same—50 per cent.

Wounds of the larynx and trachea that reach hospitals are as a rule disposed transversely across the neck. Perforating shots of the neck from large calibers directed antero-posteriorly or those traversing the neck behind the air passages are very likely to injure the great vessels or cord with fatal results. Oblique, antero-posterior, or postero-anterior shots with low velocity, effecting lodgment, are mentioned by Otis and others as capable of injury to the laryngo-tracheal tube without fatal issue. The prominence of the larynx and trachea leaves them exposed to all transverse shots across the neck anterior to the vessels and it was to this class that the hospital cases belonged formerly.

The beneficence which has come from a reduction of caliber is particularly shown in neck wounds including the laryngo-tracheal tube. Military surgeons in recent wars have repeatedly referred to the rapid recovery of uncomplicated larynx and tracheal wounds by reduced-caliber bullets. Follenfant[1] reports thirty-three cases in the Manchurian campaign with three deaths. Ten cases were discharged cured and nineteen were transferred.

Oettingen,[2] who commanded a Red Cross hospital on the Russian side in the same campaign, states that the number of tracheal wounds was small, that none proved dangerous. In those cases where large vessels were involved or in cases from shrapnel or large missiles tracheotomy was indicated, otherwise the treatment was expectant.

Hemorrhage and asphyxia are the immediate dangers to life which present themselves in wounds of the air passages. The hemorrhage arises from the neck vessels when they are injured, and asphyxia results from the escape of blood into the smaller bronchioles and air cells of the lungs. Later, pneumonia and edema glottidis sometimes arise. As a sequel stricture of the larynx or trachea occurs in a certain proportion of cases. Pvt. Jacob H. Mose, Co. A, 4th U. S. Infantry, was shot by a Mauser bullet before Santiago, July 2, while he was lying down. "The bullet entered right temple 2 1/2 inches above and 1 inch posterior to the right canthus. It passed through the superior maxilla downward and backward, cut[3] through the posterior portion of the soft palate and entered the neck. Here it became deflected, probably by the thyroid bone, and entered the thyroid cartilage, thoroughly comminuting it, cutting into the esophagus wall where, being spent, it dropped into the stomach." The patient states that

[1] M. Follenfant, Arch. de Medecine et de Phar. Mil., No. 48, p. 84, 1906.

[2] Walter von Oettingen, Studien auf dem Gebiete des Kriegs Sanitäts Wesesn im Russisch-Japanischem Kriege, 1904–1905. Berlin, 1907.

[3] Dr. Emil Meyer, Meeting A. M. Association, 1900.

he subsequently passed the bullet per rectum. There was profuse hemorrhage from the mouth and nose. He experienced difficulty in breathing and swallowing. The difficulty in breathing became so aggravated that it was necessary to perform tracheotomy August 3. He is still wearing the tracheotomy tube. There is complete obstruction in the larynx. His voice is heard in a whisper when the finger is pressed over the tracheotomy tube. The laryngoscopic appearances are described in Dr. Meyer's article.

Treatment.—Wounds of the larynx and trachea need prompt attention on surgical lines. Wounds of the front segment of the trachea without undue loss of substance are best treated by suturing if the respiratory efforts will permit. Tracheotomy is in order in all cases where dyspnea is present. Bleeding from injured vessels should be arrested by ligation and when the esophagus is wounded, if there is much difficulty in swallowing with extravasation of food in the tissues of the neck, feeding should be done through an esophageal tube introduced into the stomach through the mouth or a small flexible catheter may be passed through the nose into the stomach. When ever the wound in the esophagus is exposed and permits suturing this should be done, leaving provision at the bottom of the wound for drainage. Cellulitis being a frequent accompaniment of neck wounds, provision for drainage is never amiss in the application of the primary dressing.

FIG. 117.—Photograph of J. H. Mose, March 4, 1911, at which time he was still wearing tracheotomy tube.

CHAPTER VII

Gunshot Wounds of the Spine

Of all cases of gunshot wounds that live to receive hospital care, those suffering gunshot fracture of the spine are the most fatal, not excepting gunshot fractures of the calvarium.

Out of 642 gunshot fractures of the spine during the Civil War, in his concluding observations, Otis places the mortality in the aggregate at 55.5 per cent. He shows that the fatality increases as the seat of injury approaches the head as follows:

Cervical spine..............................	70 per cent.
Dorsal spine................................	63 per cent.
Lumbar spine................................	45.5 per cent.

In the German reports for the Franco-German War, 1870-71, the fatality on the contrary diminishes with proximity of the injury to the head as follows:

Cervical spine..............................	61.3 per cent.
Dorsal spine................................	70.9 per cent.
Lumbar spine................................	71.9 per cent.

These figures fairly represent the mortality for the preantiseptic era when the large low-velocity projectiles were in use. Although we have not yet received authentic figures of the mortality in spinal fractures for the great war in Manchuria, we have enough evidence from the Spanish-American and Anglo-Boer Wars to show that the use of antisepsis, and the employment of the so-called humane small-caliber bullet, have given us little if any encouragement looking to the reduction of the old-time mortality in gunshot fractures of the spine. The results in thirty-six cases gathered from the Spanish-American War and Philippine Insurrection, the majority having resulted from gunshot by the reduced-caliber bullet, have given us a mortality of 75 per cent. for the spine as a whole. For the Anglo-Boer War Stevenson reports the mortality in forty-eight gunshot injuries of the spine as follows:

Cervical spine (5 cases)......................	60 per cent.
Dorsal spine (41 cases)......................	60.9 per cent.
Lumbar spine (2 cases)......................	00 per cent.

He also makes use of the following very significant statement—"Fracture of the neural arch and actual lesion of the cord by bone or bullet in all regions of the spine taken together give a death rate of a little over 78 per cent." This high mortality refers to cases in which the lesion was definitely ascertained and it corresponds very closely to the mortality in the Spanish-American War just referred to in which there is a mortality of 75 per cent. for a similar class of cases. These figures establish beyond doubt that the mortality of gunshot fractures of the spine has not diminished under modern conditions and that it is as great to-day if not greater than formerly.

There is another significant feature of gunshot fractures of the spine which concerns the military surgeon especially, and that relates to their greater frequency from the effects of the new, as compared to the lesions sustained by the old armament. Borden[1] points out that the frequency of the grave injuries of the spine has been more than doubled since the introduction of high-velocity jacketed bullets. In the Civil War, with the use of the low-velocity lead bullets the relative frequency of spinal fractures was 0.26 per cent., while it was increased to 0.55 per cent. in the Spanish-American War and to 0.82 per cent. in the Philippine Insurrection. With the use of low velocities in former times, the spine received great protection from its position at the back. The comparatively low energy of the old conoidal bullets, except at proximal ranges, was sufficiently expended after penetrating intervening tissues in front of the spine to ward off fracture in the majority of cases, and the injury to the spine more often resulted in contusion of the bony structures or lodged balls. The protecting layers of tissue like the abdominal wall, abdominal contents, the thoracic walls, thoracic viscera, etc., are still a protection against spinal injury from low-velocity projectiles of all kinds, viz., spent balls, shrapnel and shell fragments. The protective layers mentioned, however, are as nothing to ward off fracture with the use of a small jacketed bullet, the caliber of a lead pencil, traveling at high velocity. Such a bullet except when it is operating as a spent ball is not deflected. Its course is forward and onward in a direct path. The bony spine itself offers but little hindrance to its penetrating effects. When it chances to strike the body of a vertebra, which is made up of cancellous tissue, it makes a clean-cut perforation with little or no splintering. The compact substance of the neural arches, the spines and

[1] American Practice of Surgery by Bryant and Buck, Lt.-Col. W. C. Borden, U. S. Army.

transverse processes are splintered more often transversely as shown by Delorme[1] and the amount of shattering is in proportion to the velocity of the missile and the resistance encountered. The bullet itself or secondary missiles like spiculæ of bone or metallic particles from the bullet traverse the canal or the immediate vicinity of its bony walls with readiness, inflicting direct or indirect injury proportional to the remaining velocity of the projectile at the time of impact.

Concussion of the Cord by Large-caliber Bullets.—In former times the anatomical lesions of the spinal cord, produced independently of direct traumatism by the ball or fragments of bone, were appreciated by the surgeons of our Civil War, as pointed out by Otis, and discussed by Lidell[2] of the Volunteer Army. The concussion was attributed to impact of the bullet against the spine. The symptoms were varied, from motor enfeeblement of the lower extremities with numbness, and sensations of "pins and needles on the one hand, to complete paraplegia, both motor and sensory, with priapism and retention of urine and feces on the other." Lidell adds further that "as the symptoms of concussion of the brain result directly from cerebral 'shocks,' so the symptoms of concussion of the spinal marrow result directly from sudden 'shock' of that organ." It was then believed that concussion of the brain and cord were both attended by minute extravasations of blood. It is doubtful if neurologists now believe that extravasation of blood is a constant accompaniment of the condition attended by temporary loss of consciousness known as cerebral concussion. On the other hand we believe it is generally admitted now that gross structural changes take place in all cases of concussion of the cord, so-called, and this is usually shown by the slow return of function or by the continuance of the symptoms in all cases of spinal cord injury not the result of direct violence.

Concussion of the Cord by Small-caliber Bullets.—The anatomical lesions of the spinal cord independently of direct traumatism by the ball or fragments of bone, and the relation which the amount of lesion bears to the velocity of the reduced-caliber bullets at the moment of impact, has been specially pointed out by Mr. Makins in the Anglo-Boer War. He classes these lesions as follows:

1. Slight concussion.
2. Severe concussion.

[1] Traite de chirurgie de guerre by E. Delorme, Paris, 1903.

[2] International Encyclopedia of Surgery, Ashhurst, 1884, Vol. IV, p. 788. By John A. Lidell, late Surg. of U. S. Volunteers.

3. Contusion.
4. Hemorrhage.
5. Intra-medullary Hemorrhage (Hemato-myelia).

He points out that any of these lesions may be caused by the "vibratory force communicated to the cord by its enveloping bony canal."

(1) Slight concussion is likened to the form of spinal concussion noticed in civil practice from causes such as railway collisions. The cases noted by Makins showed transient symptoms, there were no deaths and no opportunity to note anatomical changes.

(2) Severe concussion results when a bullet traveling at great velocity collides with the spine. There is parenchymatous hemorrhage in many of the cases and, reasoning upon the vibratory force that could induce such a trauma, it is assumed that there is more or less complete disorganization of the cord. The condition produced is allied to one of contusion in which a localized portion of the spinal cord sustains a destructive process sufficient to "interrupt the normal channels of communication with the higher centers." In a number of cases cited the symptoms are those of complete transverse lesion.

FIG. 118.—"Appearance of spinal cord enclosed in membranes in case 103 after removal from the canal. When the membranes were opened a white custard-like substance took place of the cord. Slight evidence of extradural hemorrhage existed." (Makins.)

(3) **Contusion.**—Mr. Makins distinguishes this condition from pure concussion though the two are "closely allied." In cases of contusion the post-mortem conditions showed adhesion between the cord and enveloping dura at points where the ball had struck the neural arch without fracture. The lesion of the cord which was most marked suggested injury by contre-coup. The duration of life was about five weeks. One or two segments of the cord were completely disorganized, the cord substance was represented by a "semi-diffluent yellowish material of soft consistency." When held up the membranes were prone to collapse opposite the affected portion as shown in Fig. 118. The case to which the figure refers is described as follows:

"total transverse lesion; slight intra-dural hemorrhage. Wound of entry (Mauser), below spine of scapula, close to right axilla; exit, 2 1/2 inches to left of tenth dorsal spinous process. Complete motor and sensory paralysis below ensiform cartilage, with well-marked hyperesthetic zone around trunk. All reflexes absent. Retention of urine. Incontinence of feces. Bed-sores in sacral region developed during the first two days, and seventeen days later well-developed serpiginous trophic sores developed on the outer side of each leg and continued to increase slowly until death. The paralysis remained of the absolutely flaccid variety. Great emaciation occurred, accompanied by hectic fever, the temperature ranging from normal to 102.5°. During the third week double pleurisy developed.

At the post-mortem no bone injury could be detected. The cord and dura mater were adherent over an area corresponding from the fifth to the eight dorsal vertebræ, and opposite the seventh the cord was soft and of the consistence of butter. A small intradural hemorrhage was still evident below the main lesion, not extensive enough to give rise to serious compression. General adhesions in each pleura. Cystitis."

(4) **Hemorrhage.**—This injury as a result of vibratory impulse was found in the form of surface extravasations (extra and intradural) but the more frequent kind of hemorrhage is discussed under the next heading.

(5) **Intra-medullary Hemorrhage (Hemato-myelia).**—This form of hemorrhage was nearly always associated with the changes due to concussion. Its frequency was not definitely ascertained but it was more than likely frequent and it is suggested that it was an accompaniment of nearly all grave transverse lesions not due to direct injury like compression or laceration.

In all of his experience in the South African War Mr. Makins states that he saw only one case of direct pressure upon the cord by a bullet and "none in which this was due to displaced bone fragments." He states further that the transverse lesions which were indicated by the symptoms were in his opinion due in nine-tenths of the cases to "the conditions of concussion, contusion, or hemato-myelia." This opinion based as we believe on sound judgment and sufficient experience has a great bearing on the treatment of gunshot of the spine and to us it goes far to explain certain cases which we saw during the Spanish-American War.

Concussion of the cord in this respect simulates concussion of the

brain which results from molecular vibrations. In the case of the more severe concussions of the cord from gunshot the lateral transmission of energy is so great that there is rupture of the cord substance proper with parenchymatous hemorrhage, and the presence of symptoms, which mark a transverse lesion, as though the injury had resulted from direct trauma. The macroscopic lesions noted in such cases arise from the same force that bursts asunder the tins filled with water or semifluid contents like starch-paste, as we have shown in figures when discussing explosive effects. When impact of the missile at high velocity occurs upon the bony structures adjacent to the cord and the cerebrospinal fluid, the bullet's energy is transmitted by them in the form of a vibratory force with violence in all directions, hence the rupture of vessels, disorganization of the parenchyma, and even fracture of the cord itself in some instances.

Aside from the increased frequency of spinal lesions by the new armament, on the score of superior penetration, and direct violence, we must credit Mr. Makins for emphasizing the additional explanation of the greater frequency of spinal lesions, by *the effects of vibratory force also.*

What is true of the effects of vibratory force from the projectiles of the present-day military rifle in producing the various degrees of concussion of the cord, is also true of the effects of vibratory force conveyed to the cord from the larger and more perfect revolver ammunition of the present day, and it will become more so still with the use of steel-clad bullets now employed in automatic pistols, weapons which are fast displacing the use of revolvers in civil life. Doctor Rudolph Winslow of Baltimore has recently written a very interesting paper[1] with cases in which he conclusively shows that serious and even fatal lesions of the spinal cord may be produced by revolver bullets as a result of concussion without direct impact, and he cites cases in the experience of other surgeons.

With reference to the cases resulting from the effects of the military rifle the evidence cited by Mr. Makins in the South African War is most interesting. We had a number of cases in the Spanish-American War that could only be explained on the theory of spinal concussion. The following history of First Lieut. A. S., 13th Infantry, was obtained from the records of the hospital ship Relief: "On July 1, while stand-

[1] Complete Transverse Destruction of the Spinal Cord from pistol wound, without penetration of the Spinal Canal, by Rudolph Winslow, M. D. Transactions Southern Surgical and Gynecological Association, 1910.

ing with his company at the foot of a hill during the advance on Santiago, received a wound in the neck probably from a Mauser bullet. The bullet entered on the right side just below the inferior maxillary bone, 1 inch in front of the angle of the jaw. The wound of entrance is a clean-cut hole the size of a lead pencil. The course of the bullet was backward and slightly downward, emerging at the back of the neck on a level with and to the left of the fifth cervical vertebra. At the time of the injury felt no pain at the site of the wound but says that the sensation was as if he had been grasped by the wrists and thrown violently to the ground. The wound of exit is similar to the wound of extrance. There was very slight hemorrhage. A few minutes after receiving the injury was carried from the firing line by members of his company. Removed to the first Division Hospital and during this time was conscious of his wound for the first time. Was kept there for ten days and then removed in an ambulance seven miles over a bad road to the third Division Hospital at Siboney."

We examined him July 10, and found his condition very much as described by the surgeon on the Relief on July 11, which reads as follows: "Patient was voiceless and making constant efforts to clear his bronchial tubes of accumulated mucus. Complete paralysis of right arm and leg and partial loss of power of left arm and leg. Grip of left hand very feeble. Respiration normal but an almost constant spasmodic cough. Has lost control of sphincters and has involuntary passages from both bladder and bowels. In a very exhausted condition and has profuse diaphoresis. Complains of pains all over body. Ordered a hypodermic of morphia, gr. 1/4 and atropin gr. 1/100."

"July 14: Radiograph taken by Dr. Gray shows an injury of one of the cervical vertebræ, probably the fifth. Injury seems to be to the left side of the body of the bone. Has received no treatment other than complete rest and a nightly hypodermic as noted above, which gives a good night's sleep and markedly reduces the sweating. Has regained control of the sphincters and is able to use bed pan and urinal."

"July 19: During the past six days there has been a decided improvement in the general condition of the patient. He is brighter in appearance, he can articulate more distinctly and there is a decided return of power in the right leg. The right hand is still absolutely powerless but the grip of the left hand is stronger. Appetite is good and bowels require to be moved with enemas. Unable to sleep without

morphine but the atropin has been discontinued. Circulation apparently unimpaired."

"July 21: Improvement in general condition still continues. The external wounds have healed so well that they are not noticeable except on close inspection. The hypodermics have been discontinued and trional and sulphonal substituted."

"July 22: Transferred from hospital ship Relief to hospital, Fort Porter, N. Y. The subsequent history of the case shows a gradual restoration of function of arms, legs, and sphincters. This officer had recovered sufficiently in the course of a year to be detailed as instructor in one of our military schools. He was later retired the service and died January, 1906, 7 1/2 years after the injury, cause not stated. We have every reason to believe that the lesion in this and the following case was due to vibratory concussion of the cord as described by Mr. Makins.

Pvt. A. F., Co. "C", 21st Infantry, shot at battle of Calamba, P. I., July 30, 1899, by a Mauser bullet distance 250 yards. The bullet entered right chest above nipple, over fourth intercostal space and passed downward, backward and to the left, emerging from back 1 inch to the left of the second lumbar spine. Left leg totally paralyzed immediately after injury, hemoptysis two days later. Wound healed rapidly without suppuration. Sensation returned in leg two months after injury and motion also returned in the course of another month. Examination by the writer in May, 1901, revealed weakness of the left leg as compared to the right, pains shooting down left leg and into corresponding big toe. Patellar reflex absent on left, increased on right side. Ankle clonus absent on both sides. Plantar reflex absent on left side. The patient was improving when last seen some months later.

Symptoms.—The symptoms of gunshot injuries of the spine may be divided into those pertaining to lesion of the vertebræ without cord involvement, and those with cord involvement.

Symptoms without Cord Involvement.—This form of injury was more evident by the presence of signs and symptoms from the effects of the old, larger-caliber lead bullets. As a rule the degree of comminution and displacement increases, with the caliber and weight of the missile, and danger to infection is greater. Fracture of the neural arches without cord involvement rarely occurs, while fracture of the centra or processes is apt to occur without cord involvement when the velocity of the bullet, whether it be a large or small caliber, is low.

As stated already, lesion of the centra by the reduced-caliber bullet is attended with perforation and no splintering, and, except when the bullet is animated by high velocity, there is no cord involvement unless the perforation communicates with the spinal canal. Many cases of vertebral injury are apparent only from a study of the track of the bullet as determined by direction of the wounds and the position of the body at the time of injury. Separation of the spinous processes may be indicated by deformity, pain on pressure, mobility and crepitation. Angular deformity is rare in injuries by the reduced-caliber bullet, compared to the lesions by the old-time projectile of larger caliber of the Springfield rifle type. One or more vertebræ may be implicated, and in the wars of to-day when men do much fighting in the prone position, sagittal wounds involving a number of the processes or bodies are common. Injuries to the nerve roots will be discussed in the chapter on Injury to Nerves.

Symptoms with Cord Involvement.—The symptoms of vertebral lesion with cord involvement from gunshots are the same as those in fracture-dislocation, observed in civil hospitals from other causes. Like the latter the symptoms vary with the region injured. Generally speaking they may be summed up as follows: When the spinal cord suffers violent concussion, laceration, or compression, as a result of gunshot there is more or less shock with complete paralysis below the seat of injury which takes place at once. The paralysis includes all muscles supplied by the injured segment and the segments below. Lesion of the cervical region is attended with paralysis of the upper and lower extremities. If the dorsal region is implicated, paraplegia takes place. In partial lesions one arm and one leg may show a greater degree of paralysis. Again the paralysis may show itself chiefly in both arms, or chiefly in one arm, or leg. As a rule complete paralysis follows extensive lesions, which continues till death. At times the condition is that of complete paralysis of the extensors, and from the first there is ability to flex the fingers and toes, or the ability to do so may manifest itself later. The type of paralysis varies with the extent of the injury and the location thereof. In the lower lumbar and sacral regions the form of paralysis is flaccid with tendency to atrophy. At higher levels the tendency in extensive cord lesions is for the paralysis to be flaccid at first only, later as recovery takes place it assumes the neuron type. There are sensory symptoms which consist of hyperesthesia, anesthesia, numbness, formication or a sensation of pricking with pins and needles. The pain which is usually local may be in-

tensified by movement. Often times there is no pain. Radiating pains, generally brought on by movement of the extremities, are apt to occur in cases of partial paralysis, more especially of the arms. The appearance of numbness, tingling and pain to touch, in a case of complete loss of sensation, are regarded as of favorable prognostic value. In severe cases there is often the so-called girdle sensation, which results from a zone of hyperesthesia immediately above the limit of total anesthesia. The thermic sense is sometimes lost or diminished, while the sense of touch still exists. When anesthesia is permanent the chances of recovery are bad. The reflexes are diminished or abolished when the lesion is located in a region of the cord in which the reflex emanates. For instance in lesion of the lumbar region the knee jerk is diminished or entirely absent. In the same way the cremasteric, plantar, and other reflexes when diminished or absent point to the particular part of the cord involved.

Genito-urinary symptoms refer to those of the bladder. Retention of urine is a common symptom in a large percentage of spinal-cord injuries. This is later followed by incontinence due to overflow. When the paralysis persists, instrumentation becomes necessary, this sets up cystitis as a rule, and the latter tends to alkaline urine and a tendency to the formation of vesical calculi. Sexual sensations are usually lost. Priapism is frequent in severe injuries of the cord substance, and also when the lesion is located in the cervical region.

Herpes zoster is an occasional trophic symptom. The paralyzed limbs are apt to be dry and scaly, and the growth of the nails is impaired. Decubitus is the most important of the trophic symptoms. It is most frequent over the buttocks, heels and external malleoli, the elbows and shoulders, parts where pressure is constant. Bed-sores develop rapidly, as early as the first twenty-four hours in some cases. Sloughing is assisted by infection and it is very rapid in the surrounding tissues. Septic fever generally hastens the termination of the case. Cyanosis is prone to occur, especially in lesion of the lumber region. The temperature is elevated early in the history of some cases and it ascends with the height of the lesion in the cord. In cervical lesions it registers as high as 108° F. a few hours after the injury.

Dryness of the lips and mouth with sores on the lips sometimes occurs but the distention of the intestines by gas is the most important symptom relating to the digestive system. It is a serious symptom at times because of the hindrance which it offers to respiration. It occurs when the lesion is located in the cervical and dorsal regions,

and it never results from lumbar and sacral lesions. It does not appear until about twelve hours after the receipt of the injury. Constipation is the rule but incontinence of feces may supervene later.

The pulse is at first accelerated and full, and it may intermit. The respiratory symptoms come from paralysis of the muscles of respiration and inability to relieve the accumulation of mucus in the larynx and trachea. Later edema and congestion of the lung, fruitful causes of death, are apt to supervene. Contracted pupils are common in lesion of the cord in any region. When the cervical sympathetic is involved, as pointed out already when discussing lesions of this nerve in the neck, there is narrowing of the palpebral fissure.

Diagnosis.—The diagnosis of spinal-cord injury will necessarily rest upon a consideration of the symptoms just noted. In addition X-ray evidence may assist in detecting the site of pressure by spiculæ of bone or lodged missile.

Prognosis.—A guarded prognosis should be given in all cases, even in those where the symptoms point to slight injury. When the lesion is pure concussion or the result of parenchymatous hemorrhage, the remote effects are difficult to foretell; and the danger of secondary changes in the cord are to be remembered. Meningeal hemorrhage independently of complications like meningitis is not specially fatal. Medullary hemorrhage, causing but partial symptoms of transverse lesion, may end in recovery, with remote and ulterior disabling consequences. Pressure from spiculæ of bone is unfavorable, when the ball passing adjacent to the cord is animated with a high velocity. Pressure from a lodged missile is not necessarily fatal, if the symptoms of transverse lesion are incomplete, and secondary changes remain absent. The remote effects in the following case of injury to the lower part of the cord make it worthy of mention: Mr. Edward M., New York Journal reporter, was shot, July 24, by a Mauser bullet at Las Guasimas during the advance on Santiago. The bullet entered the back 1 inch to the left of the spine opposite the sacro-lumbar articulation. There was immediate and complete paralysis of motion and sensation of the lower extremities. We transferred the patient from the Reserve Divisional Hospital at Siboney to the hospital ship Olevette June 9. He entered St. Lukes Hospital, New York, July 20, for paraplegia and partial anesthesia as a result of the gunshot wound. A radiograph taken at this time showed the bullet lodged butt end foremost 1 inch to the right of the first lumbar vertebra. August 13 he was able to move the right leg. August 17 Dr. Abbe performed a

laminectomy in the lower dorsal and upper lumbar region, cutting through the laminæ of four vertebræ on one side and breaking the laminæ on the opposite side. A small spicule of bone pressing on the cord was removed.

He left St. Lukes Hospital October 10 very much improved. He was able to walk with assistance; his left leg was weak and more or less useless. June 30, 1912, fourteen years after the injury, Mr. Marshall writes as follows:

* * * * * * *

You may or may not know that a year after the spinal operation I took matters into my own hands and arranged with other surgeons for the amputation of my left leg midway between the knee and ankle. The results of this amputation were so good that I was encouraged to hope that despite the predictions of my medical friends I might learn to walk. I therefore went out to the Michigan woods with a man who kept whitewashed steps painted on the grass for me in a row between two railings which served in lieu of crutches. After nearly five years, practice at these footsteps, I came east again under my own steam, carrying only one cane. Since then my health has steadily improved and I have hopes that next year I may be able to discard the single cane.

* * * * * * *

Very sincerely yours,
(Signed) Edward Marshall.

Colonel Louis A. La Garde,
Commandant, Army Medical School, U. S. A.,
Washington, D. C.

As stated already cervical and dorsal lesions give the worst prognosis. All cases in these regions, in which the symptoms point to transverse lesion, die in the course of about six weeks. The fatality in gunshot of the spine is often augmented by the involvement of important structures in the abdomen, chest or neck. The causes of death are direct or indirect lesions in the upper parts of the cord from which the respiratory muscles become involved. Hemorrhage in various forms—intra-dural, extra-dural, and hemato-myelia; meningitis, myelitis, cystitis, pyelitis, surgical kidney, extreme decubitus, and septicemia, all figure among the causes of death.

Treatment.—After the necessary precautions have been taken to

avoid sepsis, the treatment of gunshot of the spine is largely expectant. When the wound is located on the back, and inflicted by a shell fragment or large projectile, the dangers of infection are very much increased, and the accessible parts of the wound should be carefully guarded by frequent dressing, liberal drainage, as well as irrigation, if laceration is present.

Transport of spinal cases should be deferred for the purpose of avoiding hemorrhage, if for nothing else, as long as possible, and when it becomes necessary to move these grave cases, they are better carried on stretchers to the nearest point, where appropriate after-treatment may be properly conducted. Whenever practicable, the patient should be placed on a fracture bed. The general measures of treatment in gunshot cases do not differ from fracture which may have resulted from other causes. Constipation should be relieved by enemata and appropriate catharsis, as often as indicated. The distended bladder should be relieved every six hours by the use of a rubber catheter under strict rules to prevent infection of the viscus. Pressure bed-sores should be avoided by watchful care, and when threatened they should be treated in the ordinary way. Bed-sores of trophic origin should be kept clean and frequently dressed.

Unlike the cases of spinal injury from fracture dislocation in civil hospitals, those from gunshot by the reduced-caliber bullets especially require no mechanical appliance to maintain extension and counter-extension for the reason that as a rule there is no displacement that can be detected.

Operative interference in war wounds of the spine has yielded poor results. Now that the transmission of energy from the projectiles of the high-power military rifles is known to be a definite factor in producing complete transverse lesion in which concussion, contusion without pressure, and hemato-myelia, play the principal rôle, the futility of performing laminectomy, except for very definite reasons, is at once apparent. In recent wars those subjected to the knife have died as a rule. Possibly the operation did not hasten the end, but we know that in the large majority of the cases no operation was indicated. Fallenfant[1] informs us that in five primitive laminectomies which he saw at Moukden, death occurred rapidly. He saw no secondary operations. The experience of the British surgeons in the Anglo-Boer War was no better. We did no laminectomies following the battle of Santiago, as nearly all the cases in which the cord was

[1] Op. cit.

seriously involved with fracture died before reaching hospitals, or soon thereafter.

In the light of our present knowledge, an operation such as a formal laminectomy is only indicated when symptoms of irritation and compression are present. Compression from blood clot may be indicated by the clinical history, and compression from spiculæ of bone or a lodged missile may be indicated by the history, and X-ray evidence as well.

Surgeons are often tempted to perform exploratory operations in gunshot of the spine, and yet Mr. Makins informs us that he saw but one case in his whole series in which it "seemed possible to regret the omission of an exploration."

CHAPTER VIII

Gunshot Wounds of the Chest

With the use of the old armament chest wounds numbered 8 per cent. of all wounds treated in war hospitals. This percentage is greater with the use of the new armament and the present-day field tactics, which favor fighting in the prone position behind shelter during which the upper part of the body is more frequently and longer exposed. There is also reason to believe that the mortality from internal primary hemorrhage will be greater on the field of battle than formerly as a result of the clean-cut character of the wounds of the larger vessels in the chest.

The mortality for all chest wounds was comparatively large in the days of the old armament. Otis places it at 27.8 per cent. for the Civil War. This includes wounds of the thorax, contused, non-penetrating and penetrating wounds of the chest. Under modern conditions this fatality was reduced to 9.5 per cent. in the Spanish-American War. At Santiago we found gunshot wounds of the chest to be the most favorable of all trunk injuries outside of the heart and great vessels. We believe this to be the experience of the majority of surgeons in recent wars.

For the purpose of more careful study, gunshot wounds of the chest are divided into (1) non-penetrating and (2) penetrating.

Non-penetrating wounds of the chest include (a) Contusions in which there is no laceration or penetration of the skin, and (b) Wounds including laceration or penetration of the skin without involvement of the pleural cavity.

(a) Contusions of the chest wall are usually trivial unless the force of impact and size of the projectile are sufficient to rupture underlying tissues, or to fracture bones. Projectiles with a large smooth surface have been known to strike and contuse the chest with violence enough to rupture the heart, lungs or great vessels, causing immediate death. Contusions by smaller projectiles have also been known to make such pressure on impact as to cause rupture of vessels

in the lung tissue, and visceral pleura with resulting hemoptysis, pneumo-thorax, hemothorax, emphysema, pleuritis or pneumonia.

Treatment.—Contusions of the chest seldom require active treatment. When shock and collapse are present the condition should be treated accordingly. The chest wall on the affected side should be immobilized by strapping. If hemothorax and pneumothorax should appear the use of the aspirator is indicated in urgent cases with a view to removal of the blood and air.

(b) Laceration and penetration of the chest wall without involvement of the pleura in the wound occurred in 11,549 cases out of 20,364 flesh and penetrating gunshot wounds of the chest in the Civil War with a mortality of 1 per cent. Under modern conditions we will expect no mortality from this class of wounds. Shell fragments, deformed bullets and shrapnel balls are for the most part slow-moving projectiles which are prone to lodge, they inflict lacerated wounds which correspond in size to the shape and caliber of the missile inflicting them. These wounds are usually badly infected and they require the special attention of the surgeon to prevent suppuration. At the same time that wounds of the chest walls are not fatal, they heal slowly because of interference to the process of repair by the respiratory movements.

In the Santiago campaign wounds of the chest wall by the reduced-caliber bullet were often multiple and owing to the projectiles' superior penetration, lodged balls were seldom seen. Sagittal, oblique, and transverse shots were frequent. In one instance the projectile entered the breast above the nipple, emerged below it. It re-entered at the costal margin and passing under the skin of the abdomen it emerged from beneath the skin above Poupart's ligament. In transverse shots the bullet frequently penetrated the arm and chest wall, inflicting injury to ribs and cartilage without penetrating the chest or thorax.

Treatment of non-penetrating wounds of chest wall is similar to that of simple gunshot wounds. They seldom require more than a first-aid dressing. Foreign bodies, lodged missiles, etc., should be removed, and strict antisepsis should be practised. Bleeding vessels should be tied andwhen pain is present immobilizing the chest wall by strapping will prove very effective.

Penetrating wounds of the chest were very fatal in the Civil War and the wars fought with the old armament. Otis makes record of 8715 cases treated with a mortality of 62.5 per cent. The French Army had a mortality list of 91.6 per cent. in the Crimea; and the

English troops suffered a mortality of 79.2 per cent. in the same campaign. Generally speaking, 60 per cent. of the penetrating gunshot wounds in former wars died. In campaigns which entailed privations on account of weather, lack of proper nursing and above all, enforced transport in all kinds of uncomfortable vehicles, the mortality was rated above 90 per cent. The humane character of the reduced-caliber bullet in visceral wounds is nowhere better exhibited than it is in those penetrating gunshot wounds of the chest that survive to reach hospital treatment. Out of 283 cases reported from the Spanish-American War and Philippine Insurrection our mortality was 27.5 per cent. as compared to 62.5 per cent. in the Civil War. Better still, Stevenson reports that out of 214 cases which were treated in the Boer War only thirty died, making the death rate 14 per cent. The variation in the death rate of these two campaigns may be due to the distribution of the relief personnel with the army. With us at the battle of Santiago especially, our surgeons had their dressing stations close to the fighting line. The severely wounded who would ordinarily have died on the field were treated and noted as cases belonging to those treated in hospitals. The same explanation holds good for the part of the war in the Philippines—our surgeons took note of the wounded on the line as soon as they were hit, hence the larger percentage of fatalities.

The humane character of gunshot wounds as revealed in late wars was most gratifying to us because, as already stated in another chapter, experimental studies with the factors concerned in causing destructive effects in wounds had led us to predict a favorable outcome in gunshot wounds of the lungs. The small frontage of the jacketed bullets of reduced caliber and the minimum amount of resistance in lung tissue favor the occurrence of humane wounds. Military surgeons in the Anglo-Boer and Russo-Japanese Wars all agree upon this point. Oettingen[1] from the Manchurian campaign says that when injuries of the lungs were simple, they were among the most harmless of those met in war. Fallenfant[2] collected the results in 945 gunshot wounds of the lungs and pleura in the hospitals at Moukden with a mortality of 3.67 per cent. He states that a certain number of officers and men were able to resume their duties in a few weeks. Graf and Hildebrandt[3] mention the case of a Chinese soldier who had strength suffi-

[1] Op. cit.

[2] Op. cit.

[3] Graf und Hildebrandt. Die verwundungen durch die modernen Kriegsfeuerwaffen. Vol. II, Berlin, 1907.

cient to swim five hours after receiving a fatal gunshot wound of the lung. We found it difficult to restrain the patients shot through the chest after the battle of Santiago. Many of them had neither dyspnea, pain, nor hemoptysis, so that it was difficult for them to understand the necessity of keeping quiet. While inspecting the wards of our hospital four days after the battle, the beneficence of wounds by the reduced-caliber bullet was brought forcibly to our attention when we found two soldiers late in the night sitting on the ground engaged in conversation over the events of the battle, while smoking cigarettes. One of them had been shot through the right lung and the other had received a perforating gun-shot of the cranium over the parietal region. The latter had been operated upon that day for the removal of loose fragments of bone at the wound of entrance.

We had some remarkable recoveries from gunshot wounds of the chest as follows:

In the case of Pvt. E. O., Company "C", 16th Infantry, the ball, a .45-caliber shrapnel, entered just below the angle of the right scapula and coursing forward lodged under the skin in front between the seventh and eighth ribs having penetrated the lung, diaphragm and liver. There was hemoptysis for a few days and slight elevation of temperature. Lt.-Col. N. Senn,[1] U. S. V., reported the temperature normal on the tenth day and recovery seemed near completion on about the nineteenth day.

Pvt. J. B. Senacal, Co. "G", 22d Infantry, was shot by a Spanish Mauser bullet on July 1. The bullet entered the back just below the angle of the left scapula. It ranged upward through the lung, neck and lower jaw, making its escape through the alveolar process opposite the right bicuspid, furrowing the tongue. We saw this case shortly after the occurrence. He suffered from partial paralysis of the left arm as a result of injury to the brachial plexus. There was profuse hemoptysis for the first few days. Recovery was uninterrupted after the third week. He is living and pensioned at the rate of $30 per month.

Private Harry Mitchel, Co. "C", 7th Infantry, wounded July 1, by a Mauser bullet entering over left acromion process, and passing through the apices of both lungs. The bullet escaped from the chest wall at the fourth intercostal space just above the right nipple. There was moderate hemothorax right side. This man made a good recovery. He is now pensioned at the rate of $24 per month.

[1] Hispano-American War, letters and papers by N. Senn., Surgeon U. S. Vols.

Henry T. Darby, Co. "D", 13th Infantry, received a gunshot wound of the chest on right side from a Mauser bullet July 1. Wound of entrance above angle and to outer border of scapula. The bullet passed transversely forward and escaped through the fourth intercostal space on the left side posterior to the mammary line. He was transferred to the hospital ship Relief July 9, at which time Col. Senn reported his condition as follows: "great difficulty in breathing; he was pale, prostrated, temperature 102° F. . . . . . copious pleuritic effusion on left side. Chest was opened by an incision through sixth intercostal space in the axillary line July 11. About 3 pints of fluid blood escaped. Gauze drainage. The lung expanded rapidly and the patient commenced to improve." He was subsequently examined for a pension and rated at $30 per month until 1905, when he was dropped, whereabouts unknown.

Symptoms and Complications.—The symptoms of perforating gunshot of the chest are extremely variable. In some cases there are but few symptoms.

Shock is not always present, but it seems to be most marked in cases with a pronounced injury to the chest wall. Pain is not constant. It is sometimes severe when fractured ribs complicate the chest wound and when the pleura is more or less involved in the trauma.

Hemoptysis is present in about 75 per cent. of the cases, according to Stevenson's observation in seventy-eight cases. It lasts three or four days as a rule, it is generally scanty and seldom calls for treatment. Cough is generally slight, and of short duration. Hemothorax is a common complication and one of the most serious when it is copious and persistent. There is slight hemorrhage in the pleural cavity in nearly every case of pleural involvement. Such cases are never serious and they are marked by early convalescence. Large effusions of blood generally arise from wounds of the chest wall rather than the lung tissue. Makins states that hemothorax of parietal origin occurs in 90 per cent. of the cases as a result of direct injury to intercostal vessels by the projectile or from laceration by pieces of fractured ribs. When it arises from the lung, there is co-existent hemoptysis. The onset of hemothorax is gradual as a rule, and it seldom occurs before the second or third day. It is a recurrent hemorrhage and like recurrent hemorrhage in other parts of the body it is influenced by excitement, transport, etc. When the hemorrhage issues from the large vessels at the root of the lungs the hemothorax occurs immediately and it is rapidly fatal. The symptoms indicating the appearance of hemothorax are

rapid pulse, pain, cyanosis, dyspnea, a certain degree of restlessness and a rise of temperature which at first is ascribed to absorption of fibrin. It has been noted that accessions of temperature occurring later from time to time may be due to fresh hemorrhage with subsequent absorptions of fibrin and not to sepsis. The remaining symptoms of hemothorax are those of fluid in the pleural cavity. Pneumothorax was a common symptom with the use of large-caliber bullets but it is seldom observed after wounds by the new armament because of the very small wounds of entrance and exit in the lung proper. Makins saw it in three cases out of about a half dozen wounded by the Martini Henry bullet which about corresponds to our old .45-caliber 450-grain lead bullet shot from the Springfield rifle. But he saw the same complication in less than 3 per cent. of perforating chest wounds by the reduced-caliber jacketed bullet. Convalescence was slow and tedious in those injured by the larger caliber.

Empyema increases in frequency with the caliber of the bullet because the amount of dirt and infected clothing which is carried in the wound is in proportion to the sectional area of the bullet. Infection may also come from bile and fecal matter when the projectile traverses an intestine from below. Secondary infection sometimes takes place after aspiration or incision for the relief of hemothorax or removal of a lodged ball. Empyema as a result of primary infection by a reduced-caliber bullet is uncommon unless the shot is delivered at proximal ranges against a rib with shattering of bone. In such a case the character of the wound augments the tendency to the development of infection from the dirty skin, and possibly the bullet.

Pleurisy and Pneumonia.—Pleurisy is very rare. A certain amount of consolidation necessarily takes place about the channel of a gunshot wound in lung tissue, but pneumonia as a clinical entity is seldom seen except in cases followed by exposure.

Abscess of the lung is rare from gunshot wound. It is commonly associated with the presence of foreign bodies like fragments of missiles, bone, or pieces of clothing. Lodged bullets have been coughed up from abscess cavities with the abscess contents and again the abscess about the missile may point outside. Removal of the foreign body in any way is generally followed by rapid recovery. Gangrene of the lung is a very rare complication. But two cases were reported in the Anglo-Boer War, both ending in death.[1]

[1] Gunshot Wounds by C. G. Spencer, Major, R. A. M. C. Henry Frowde, Oxford University Press, 1908.

Treatment.—The first indication of treatment consists in the application of a clean dressing to a clean field. The patient should be kept in the prone position and propped up enough to insure comfort. Transport should be delayed in all cases until healing has taken place and the danger to complications has passed. Our cases at Santiago were an exemplification of the evil effects of early transport, as pointed out by Greenleaf[1]. He collected the history of twenty-four cases in the Santiago campaign, fifteen of whom recovered without complications. Hemothorax was present in the remainder, and in six of these the hemothorax ended in empyema as a result of infection. Our wounded were on the move from the time they were hit until they were received in the hospitals at the North. They were first transferred from the field a distance of ten to twelve miles over bad roads in escort wagons mostly. Upon reaching the Divisional Hospital at Siboney, they were transferred in small boats in a rough sea to transports which had no conveniences for the care of the sick, as a rule. The passage to northern points took from five to nine days, so that during the active stage of repair the wounds were seldom quiet. Makins states that under favorable field conditions hemothorax occurs ordinarily in about 30 per cent. of the gunshot cases of the chest and that at least 90 per cent. suffer from this complication in varying degrees of severity when early transport takes place. Manteuffel,[2] Oettingen and all the reporters from Manchuria agree that formal evacuation is contraindicated, and they lay particular emphasis on the advisability of treating chest cases near the first-aid zone whenever practicable.

Fortunately in the majority of cases the hemothorax is slight and requires no active surgical interference. With rest in the prone position, and morphine when indicated, absorption takes place in a short time. It is a safe rule to delay operation for some days to permit healing of the wounded vessels, otherwise removal of the blood from the pleural cavity is apt to disturb coagula about the bleeding point with a recurrence of hemorrhage. When the blood is sufficient in amount to embarrass the heart or the respiratory movements, it may be removed by aspiration. It is not necessary to remove all of the fluid blood. After removing it in part absorption of the

[1] Gunshot wounds of the chest in the Spanish-American War by H. S. Greenleaf, Asst. Surg., U. S. A., N. Y. Med. Jour., 1899, No. 70.

[2] Archiv. für Chirurgie, 1906, p. 711.

remainder is often promoted, and if it does not disappear entirely the operation may be repeated a second or third time.

The source of hemorrhage in hemothorax is more frequently from the intercostal arteries or the mammaries. The treatment of such a condition is ligation of both ends of the bleeding vessel. In cases of hemorrhage from an intercostal, pressure by Desault's method which is accomplished by pressing the center of a square piece of gauze in the wound with the finger and subsequently packing the pocket left by the removal of the finger with loose gauze is a very effective plan of treatment. The corners of the gauze originally pressed in by the finger are pulled upon to make pressure on the internal surface of the wound next to the sternum or ribs. The neck of the sack thus formed is twisted and tied close to the chest wall and subsequently transfixed by a large safety pin.

Failure of absorption of large quantities of clotted blood should be met by incision or the resection of part of one or more ribs and the subsequent employment of irrigation. When a hemothorax undergoes suppuration from any cause the treatment is the same as that for empyema—incision, resection of rib, drainage.

All operations for hemothorax should be done under the strictest antisepsis with reference to the field, the instruments and dressings, to prevent infection of the blood clot, which is proverbially a favorite pabulum for the development of septic microorganisms.

Fractures.—The older writers placed special emphasis upon the gravity of penetrating gunshot wounds of the chest when fracture was present, and this was considered especially true if the bone lesion was at the point of entrance. It was also believed by writers during the days of the old armament that a perforating gunshot wound of the chest could not take place without fracture. This statement in itself shows how common fracture must have been in gunshots by the large calibers. Otis states that out of 8715 cases of penetrating gunshots of the chest, fracture of the ribs is noted in 505 cases of which 204 were fatal. He believes fracture was nevertheless present in the majority of the cases. Fracture of the sternum is noted as a complication in fifty-one cases, fracture of the vertebræ in ninety-two; of the clavicle in 136, of the scapula in 375 cases of the 8715 penetrating chest injuries.

Fracture of the ribs by the reduced-caliber bullets is in the form of gutter, or notching of the costal margin. When complete solution of continuity takes place the comminution is localized, the spiculæ

are small and the fissures are short. The costal cartilages show no fracture, they are grooved or perforated. Gunshot of the sternum is always guttered or perforated, without fracture.

Fracture of the clavicle is attended with comminution on account of its compact structure and the area of fracture is not so circumscribed as it is in fracture of the ribs. In the case of Colonel E. H. Liscum, U. S. A., at the battle of Santiago, a Spanish Mauser bullet splintered the middle third of the clavicle badly. Spiculæ of bone were removed from the wound shortly after the injury and two weeks later bone fragments were again removed and the jagged edges of the inner fragment were excised. But 1 cm. of the acromial end remained after final healing (Johns Hopkins Hospital records).

Gunshot lesion of the scapula generally exhibits clean-cut perforations with no special features as to symptoms or prognosis.

Symptoms of Fracture of the Ribs.—Fracture of the ribs often shows none of the symptoms of fracture present from other causes such as pain, stitch on inspiration or crepitus. This fact was noticeable in a number of our cases in the Santiago campaign. The absence of symptoms is seen especially in transverse shots through the chest. The lesion in such cases may be perforation or notching. In either of these lesions there is no *raison d'être* for symptoms of pain or crepitus. Transverse lesions are frequently marked by complete solution of continuity with total absence of bone substance opposite the point of impact, so that the fragments fail to touch. In such cases crepitus is absent, and most generally pain and stitch on inspiration are not complained of. In longitudinal shots complicated by complete fracture of two or more ribs the comminution is generally marked. In these cases pain and dyspnea are often severe.

Treatment of Fractured Ribs.—The wound should be explored to remove any loose spiculæ of bone. The chest should be immobilized at once in all cases. The indications for fixation are especially necessary in multiple fractures.

Lodgement of Bullets in the Chest.—Retained bullets in the chest were of common occurrence with the use of the low-velocity weapons. Otis in his series of 8715 cases of penetrating gunshot wounds of the chest mentions 484 cases of missiles which entered the chest and which were believed to have lodged within. His notes contain record of 3463 cases in which no mention is made as to exit or lodgement. In the wars of the present day lodgement of missiles is chiefly confined to shell fragments, shrapnel balls and rifle projectiles

having low remaining velocities. Missiles usually find lodgement in the chest wall, lung, pleural cavity or against the spinal column. The exact location of the foreign body is first to be determined by the X-ray. No attempt should be made to remove a lodged missile unless it causes untoward symptoms. When easily accessible, in the chest wall, its removal should be undertaken with full knowledge of the risks involved in setting up sepsis of the underlying pleura, and even in this location, if the projectile causes no inconvenience it is better to let it remain undisturbed lest infection with acute empyema result from attempts at removal. After correctly locating a missile inside the pleural cavity, if it gives pain and other symptoms of irritation, it should be cut upon and removed. Projectiles inbedded in lung tissue and against the spine are best let alone.

Gunshot Wounds of the Heart and Pericardium.—When a gunshot wound of the heart occurs, death usually results in a very few moments. Still, wounds of the pericardium and heart followed by recovery were noted even in the days of the old armament. The marvelous escape of the heart and pericardium from apparent injury in shots traversing the cardiac area has been commented upon by nearly all observers in recent wars. These cases of unexpected recovery are said to be due to the way in which the heart and great vessels are held together by loose areolar tissue which favors a certain amount of displacement at the moment of impact by a bullet impressed with a low remaining velocity. Some of the unexpected recoveries from wounds of the cardiac area have also been ascribed to the variability of the size of the heart from systole to diastole.

Follenfant[1] states that Manteuffel saw five cases, and that Doctor Butz observed three cases of wounds of the heart in the Manchurian campaign which recovered without treatment. Makins from the Anglo-Boer War reports that "perforating wounds of the heart were probably fatal in all instances, in spite of the fact that in some patients who survived, the position of wound apertures on the surface of the body made it difficult to believe that the heart had not been penetrated."

We believe Mr. Makins' statement to be too sweeping. The literature of heart injuries contains many references to recovery from incised wounds of the pericardium and heart. If recovery from gunshot wounds of the heart were possible formerly they should be more apt to recover now from the lesions inflicted by small jacketed bullets.

[1] Op. cit.

especially those of the 6.5-mm. bullet of the Japanese, or the later pointed bullets recently adopted by the English, German and United States armies when a regular impact is accomplished. The slit-like apertures of entry and exit so often noted in the skin and other tissues are not unlike incised wounds inflicted by a knife blade from which, as we have already stated, authentic instances of recovery have been noted.

In seventy-two men wounded in the cardiac area Fischer found the location of the wound of the heart on post-mortem to be as follows:

Right ventricle	22
Left ventricle	16
Both ventricles	4
Right auricle	2
Left auricle	1
Apex	1
Base	1
Septum ventriculorum	1
Entire destruction of heart	1

Symptoms.—Among the symptoms of wound of the heart and pericardium are those of great distress, shock, irregular action of the heart, syncope, dyspnea and severe pain in the cardiac area. Hemopericardium when present more often appears some days after the receipt of the injury. At first the fluid blood flows through the pericardial wound into the pleural cavity or outside. Later when the pericardial wound becomes closed by coagula, accumulation of blood in the pericardium takes place and the symptoms of hemopericardium appear, as evidenced by increase of the cardiac area, loss of apex beat, and the presence of friction sounds from the inner lining of the pericardium rubbing against the coagulated blood. In cases of suppuration the symptoms are very similar, with the added presence of an elevation in temperature.

Treatment.—When symptoms point to the presence of blood or septic matter in the pericardium with urgent dyspnea, paracentesis of the pericardium should be practised to believe the distress and impending death. The needle should be inserted 2 inches to the left of the median line in the fourth or fifth interspace, pushing it continuously until no further resistance is encountered, when fluid will flow if present. The patient should as a rule be recumbent during the operation. The operation may be repeated if it was accompanied by relief in the first instance. If pus is present it is better treated by open incision and drainage.

Wound of other Thoracic Structures.—Gunshot wound of the thoracic duct does not figure in medical literature. Otis reports no instance in the surgical records of our great Civil War, and we find but one reference to such a case in the experience of Bonet as quoted by Delorme.[1]

Wound of the thoracic portion of the esophagus must be very rare. Otis mentions one solitary instance in the Civil War. Spencer stated that one case was reported from the Anglo-Boer War in which dysphagia was the only symptom, possibly as a result of bruising. Injury to the thoracic part of the esophagus in battle is more than likely accompanied by spinal or great-vessel injuries or both, cases which figure among the dead on the field, hence their rarity in military hospital reports. Again, authors cling to the notion that the loose tissue of the mediastinum permits structures like the great vessels and the esophagus to be pushed aside by the pressure of the bullet. This explanation can only be tenable in the case of bullets having low remaining velocities.

[1] Op. cit., pp. 719–20.

CHAPTER IX

Gunshot Wounds of the Abdomen

No class of wounds has given such divergent results between the practice of civil and military hospitals as those from gunshot of the abdomen. Our civil confrères had attained results in the surgical treatment of abdominal wounds mostly from pistol shots that had served to lend great hope for the outcome of abdominal wounds inflicted by firearms in modern wars, but alas! this hope was turned to bitter disappointment in the Spanish-American War, the first to be fought with the use of the new armament. As far as present observation and experience have gone, if penetrating wounds of the abdomen in the field recover more often than they did formerly, we regret to state that it is not through the intervention of surgical care, but rather due to the character of the wounds inflicted by the new military rifle under certain battle conditions only, and that the skill and painstaking details of expert surgeons avail but little in the management of the large majority of gunshot wounds of this region. Various reasons have been given in explanation of this fact, and we will endeavor in this chapter to rehearse the points at issue and to lay emphasis on those which appear to us to be chiefly concerned in this unwelcome result.

Gunshot wounds of the abdomen are very properly divided for the purpose of study into:

(1) Contusions.

(2) Non-penetrating flesh wounds.

(3) Penetrating wounds of the abdominal cavity.

(4) Perforating wounds of abdomen.

(1) Contusions of the abdomen may be (a) confined to the abdominal wall, or (b) the contusion may in addition be accompanied by rupture or other injury of some of the viscera or blood-vessels in the abdominal cavity proper. Simple contusion of the abdominal wall may be accompanied by superficial extravasation of blood, hematoma of considerable extent, or rupture of muscle fiber. As a result of gunshot in war, the condition is rare as compared to contusions from other causes, such as that attending the commotion of battle—vio-

lence from the hoofs of horses, the wheels of field artillery, blows from rifle butts, etc.

Gunshot contusions of the abdomen with or without visceral involvement are caused by large shot, shells or shell fragments when moving at low velocity, or in a direction at a tangent to the surface. They also arise from rifle projectiles and shrapnel balls when striking with low velocities against the body proper or part of the accoutrement, like a belt buckle.

The symptoms of contusion may be attended by rupture of muscle which is indicated by a depression between the muscle fibers at the point of impact, or there may be tumefaction indicating hematoma. Nausea and vomiting are common with falling or rising temperature. Shock is not an infrequent symptom, and when the blow is delivered in the neighborhood of the solar plexus, as on the belt buckle from a spent ball, the shock has been so great in some recorded cases as to cause prolonged insensibility, and death.[1]

Contusion with rupture of viscera is rare from gunshot. Otis reports forty-one cases from our Civil War with twenty deaths. Among these were one rupture of the liver, and one of the spleen, three of the kidney, five of the intestines and thirty-one ruptures of viscera undetermined.

In recent wars contusions of the abdominal wall alone and contusion attended with rupture of viscera have not been of frequent occurrence. They are not referred to by Makins in his Surgical Experiences in South Africa, while Stevenson refers to fourteen cases from various kinds of missiles. A case by Sir Watson Cheyne in the Anglo-Boer War and quoted by Stevenson is one of the most remarkable of any contusion of the abdomen with visceral injury. "A man was shot 1 inch above the umbilicus by a rifle-bullet which either was travelling at such low velocity or grazed the abdominal wall so obliquely that it only removed the cuticle over an area of 1 inch by 1/4 inch, leaving apparently the true skin uninjured. The man died on the third day from peritonitis, and at the post -mortem two lacerations of considerable size were found in the ilium, immediately beneath the site of contusion. The specimen, skin and intestine, is now in the R., A. Museum." In our opinion such an occurrence more than likely took place by the impact of a spent bullet against the abdomen when the intestines were very much distended with gas or fluid contents, more than likely the latter. A knuckle of intestine pressing against the

[1] Delorme, op. cit., Vol. II, p. 746–7.

wall at the point of impact no doubt received enough of the remaining energy of the bullet to cause rupture.

In the Russo-Japanese War Graf and Hildebrandt[1] state that contusion with rupture was rare and contracted mostly when the men were lying prone, from well-spent balls. When the official reports of the great war in Manchuria have been published we will no doubt be better able to discuss the frequency of contusion of the abdominal wall by the new armament with and without visceral injury.

Symptoms of contusion of the abdomen with rupture of viscera are quite similar to those of contusion of the abdominal wall, but in addition there are symptoms of a serious and persistent kind which refer to internal hemorrhage, lesion of the intestine, or rupture of solid viscera like the kidney, liver, spleen, etc. The symptoms are not always definite in the earlier part of the clinical history.

In the less severe cases, viz., those that live long enough for the development of symptoms, there appears in addition to the earlier symptoms of shock, pain, vomiting and rigidity of the abdominal wall, some later symptoms which point to hemorrhage or peritonitis. The significance of these symptoms should not be overlooked because they bear on the extent and kind of injury, and because they are of much value in the subsequent treatment. In the presence of internal hemorrhage, the patient becomes pulseless and very restless; pallor and difficult breathing appear and the peritoneal cavity fills with blood as evidenced by dullness in the flanks. The dullness will vary as it does when present in other cavities, by varying the position of the patient. Retention of urine is a frequent symptom in the presence of hemorrhage. The source of hemorrhage may be rupture of one of the solid organs, a blood-vessel, or the intestine; but most generally it results from fracture of the liver or spleen. Peritonitis usually follows rupture of some part of the intestinal tract. In such a case, the pre-existing tenderness, pain, rigidity and vomiting become more intensified, and tympanites becomes more marked.

The **diagnosis** of internal injury should be based upon a survey of the symptoms. In some cases, the symptoms, at first, are more or less misleading since they are in no wise in keeping with the severity of the injury; and again, a marked lesion is not always accompanied by profound shock, or other symptoms of a grave injury. For instance slight contusion of the abdominal wall has been known to coexist with severe shock, or the symptoms may be trivial in the beginning,

[1] Op. cit.

when extensive lesion is present. The persistence of the symptoms is far more significant than their severity. In a case of rapid pulse, and persistent vomiting, with increasing rigidity of the abdominal wall, peritonitis from intestinal rupture is almost certain to be present.

Treatment.—In simple contusion of the abdominal wall the treatment is purely expectant. Shock if present is treated in the usual way. The patient should be placed in bed with shoulders elevated and knees drawn up to relax the abdominal muscles. Morphia for the relief of pain should be withheld as long as possible since its effects are prone to mask some of the important symptoms of visceral lesion when present. In the first twenty-four hours it is better to depend upon position and fomentations. If opium is to be used in any form it should be administered as morphine hypodermatically.

When the primary symptoms of shock, pain, nausea and vomiting persist, or if dullness indicates the presence of blood in the abdominal cavity, the abdomen should be opened at once. The sooner this is done after a reasonable diagnosis has been made the better will be the chances of saving life. Cases of visceral injury from contusion when let alone all die; they are more fatal than penetrating wounds by the new armament, as we will show later on. For this reason unfavorable environment and fear of setting up sepsis by opening the abdomen in field hospitals should form no excuse for delaying operation. A man dying of internal hemorrhage has only one chance for life and that lies in a laparotomy. Laparotomy for impending peritonitis from rupture of a hollow viscus is just as imperative. As soon as rupture of any part of the intestinal tract becomes known or strongly suspected by the persistence of symptoms of tympanites, rigidity of the abdominal muscles, and rapid pulse, the abdomen should be opened and the ruptures properly sutured, the peritoneum cleansed of blood clots and fecal matter. Shock should be combated with appropriate remedies including hot salt solution in the abdominal cavity. The operation should not be prolonged any more than is absolutely necessary. The abdominal incision should be brought together by interrupted silkworm gut to include all layers.

(2) **Non-penetrating Wounds oi the Abdomen.**—The chief interest in this class of wounds lies in the difficulty which the surgeon often encounters in differentiating non-penetrating from penetrating wounds. Thanks to modern methods of treatment there is now no mortality attending non-penetrating wounds of the abdomen, since they are classed with simple flesh wounds. Of sixty-four cases

reported by the Surgeon-General of the U. S. Army during the Spanish-American War and Philippine Insurrection there was no death, while the death rate in 8612 recorded cases in our Civil War and the Franco-German War, taken together, give an average mortality of 8.3 per cent.

Non-penetrating wounds of the abdomen are less frequent with the use of the new armament because of the greater penetration of the new military rifle bullet. They often present difficulty in diagnosis. The gutter wounds, and those with superficial tracts, indicate very definitely the non-penetrating character of the wounds. In the case of a lodged ball its position is easily defined by palpation or by the X-ray. The greatest difficulty as pointed out by Mr. Makins was found in those wounded in "the thicker muscular portions of the lower part of the abdominal and pelvic walls." Wounds of the colon and sigmoid flexure so often give no symptoms that penetration of them is frequently undetected.

Treament.—Non-penetrating wounds of all kinds are treated on the principles laid down for infected wounds. They should be cleansed of shreds of clothing and foreign matter when lacerated and when the parts of the wound are easily accessible. In the case of shots travelling immediately under the skin for any distance it is well to establish drainage at different points or to lay the channel open and treat the wound from the point of entrance to that of exit as an open wound. Missiles when properly located should be removed. Splinters from grenades are said to cause extensive multiple wounds which heal slowly on account of loss of muscular and other tissues.

(3) **Penetrating Gunshot Wounds of the Abdominal Cavity.**—Under this designation we include those gunshot injuries which penetrate the peritoneal cavity without injury to either the omentum, mesentery or other viscera. Although this classification is adhered to, we recognize that so-called penetrating wounds often include injury to the omentum and mesentery. This is no doubt in part the class of wounds that has recently come forth in sufficient numbers to puzzle military surgeons, and a host of civil surgeons who, for love of country, and a desire to ameliorate suffering, have rendered valuable service with armies in recent wars. The wounds referred to penetrate the intestinal area, but they give no special indication of visceral injury, and they often or nearly always recover. The idea that a projectile is capable of penetrating the peritoneal cavity without injury to the viscera is not new. It is mentioned by the

older writers, who under their expectant plan of treatment had reasons to suspect such an occurrence in patients that recovered. Otis mentions such cases, and one in particular which was verified by post-mortem, in a soldier who died from injury to parts outside the peritoneal cavity as follows: "A round musket ball entered the left ninth intercostal space; point of lodgement, body of second lumbar vertebra. The bullet traversed the chest, perforating the lung and diaphragm, it grazed the stomach, colon and coils of jejunum. The soldier survived three weeks. At post-mortem no evidence of peritonitis was present. Death was due to lung complications and hectic from a psoas abscess." In another case the ball passed obliquely across the abdominal cavity through the convolutions of the small intestines "without apparent injury to any portion of the digestive tube."

The Kaiserliche Sanitäts Bericht, 1870-71, gives strong presumptive evidence of the existence of this class of wounds by the larger-caliber military rifles. Of 1534 gunshot wounds of the abdomen involving the peritoneal cavity thirty-three are reported to have been wounds of the peritoneum alone and in nine of these the bullet penetrated the abdomen transversely without injury to the intestines. The surgeons in civil practice have frequently noted such cases from the effects of low velocity missiles from pistols and revolvers.

After the introduction of the reduced-caliber rifles it was thought that injury to the peritoneum alone might be less frequently observed because of the superior velocity of the new bullet, which causes it to cut like a knife, but the large number of recoveries in recent campaigns tends to negative this view. Peritoneal wounds seem to be mostly confined to shots about the regions of the jejunum, ilium and transverse colon, and not so often to shots over the stomach, duodenum, the ascending and descending colons. Shots over the latter, and the solid viscera, are more readily suspected of inflicting perforation, because of the fixed position of the organs.

At Santiago we saw men who had recovered from abdominal wounds by the Spanish Mauser bullet when the track of the bullet, as judged by the location of the wounds of entrance and exit, made it impossible for the bullet to have travelled outside of the intestinal area. These shots were mostly disposed antero-posteriorly, but in one case in particular the shot traversed the abdomen obliquely from one flank to the other. The patient recovered without evidence of either general or local peritonitis, much to the surprise of the surgeons who saw the case.

Various explanations have been given to account for these beneficent effects of the new bullet. One is that the small intestine is suspended by the mesentery in a way to permit free movement, and as the coils of gut are superimposed when the bullet's track takes certain directions, the missile is able to travel parallel to the long axis of the coils without perforation.

One of the most indubitable instances of gunshot penetration of the abdomen which goes far to support the contention that the movable intestine is capable of being pushed aside to avoid perforation

Fig. 119.—Shows the denuded and lacerated intestine in Thornburg case.

occurred in the practice of Major R. W. Thornburg, U. S. A., as follows: "Private William Ummack, Co. "H", 30th U. S. Infantry, recently entered Latterman General Hospital, San Francisco, Cal., for gunshot wound of the abdomen self inflicted. The weapon used was the U. S. Army reduced-caliber magazine rifle loaded with a full-charge cartridge. Wound entrance 3×2 cm. diameter, located 5

cm. to left and 2 cm. above the umbilicus. Wound of exit 1 cm. in diameter, located directly above left posterior superior spine ilium, on a level with umbilicus. There were fifteen wounds of ilium, three of descending colon, numerous wounds of mesentery. No complete intestinal perforation discovered. Twelve ruptured blood-vessels found. Intestinal wounds consisted of destruction of peritoneum and muscular coats. Wounds of viscera principally due to explosive effect of cone of fire proceeding base forward. Muzzle of rifle was

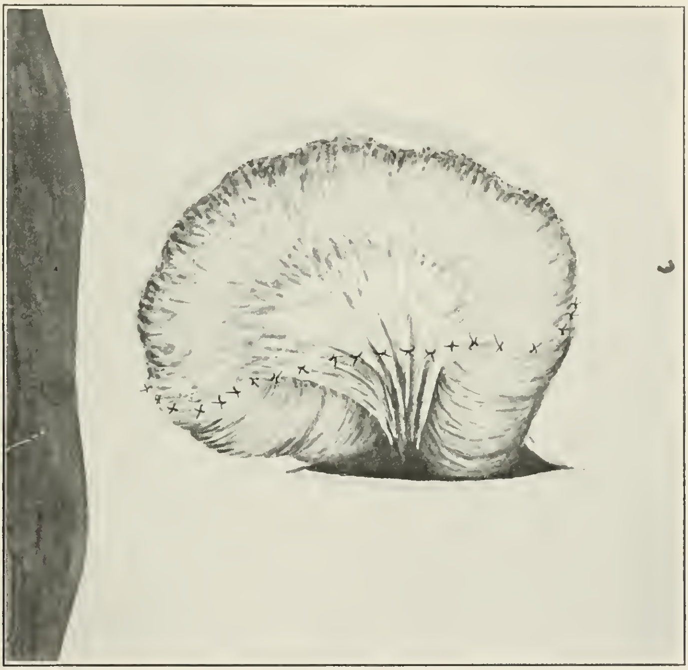


Fig. 120.—Shows omentum covering lesion in wound of mesentery in Thornburg case.

placed against body, olive drab woolen shirt and cotton undershirt perforated by bullet.

When received at hospital patient was so much shocked that the surgeons refrained from doing a resection of the wounded intestine. The wounds of the colon were inverted, blood-vessels tied, and the wounded ilium and mesentery were covered by omentum as shown in Figs. 120, 121. Fig. 122 shows the protruding gut and a piece of omentum. Fig. 119 depicts the character of the lesion of the denuded

and lacerated intestine. The patient was drained front and rear and placed in Fowler's position with Murphy drip for twenty-four hours. There was at no time any infection and a perfectly normal convalescence and recovery were the result."

It is difficult to conceive how the ball and the explosive charge could have traversed the abdominal cavity as indicated in the history of this case without perforating the intestinal tube except upon the

FIG. 121.—Shows omentum covering lesion in wound of mesentery in Thornburg case.

theory of displacement by the pressure which was exerted upon the tissues in all directions. That the intestinal area can be traversed by a rifle bullet without opening the small intestine seems also to have been demonstrated to the satisfaction of the staff of A Civilian War Hospital. The authors quote the case of Mr. Lenthal Cheatle as follows: "A private was shot right across the abdomen in a fight to the west of Pretoria, and died forty-eight hours later. The bullet had entered low down in his right lumbar region, and had emerged near the left anterior superior spine of the ilium, where it finally lodged, after pass-

ing through the skin for half its length; it was a "Jeffreys sporting bullet." The post-mortem examination showed that the projectile had passed through the cecum transversely, close to its posterior wall, and had passed out through the sigmoid flexure, in which it made a large rent. It was thus clear that the bullet had passed right across the cavity of the abdomen, and, having entered it posteriorly and passed from behind forward, it had thus traversed the abdomen in its antero-posterior diameter as well. In spite of this, however, the coils of small intestines showed no wound or abrasion, although there was

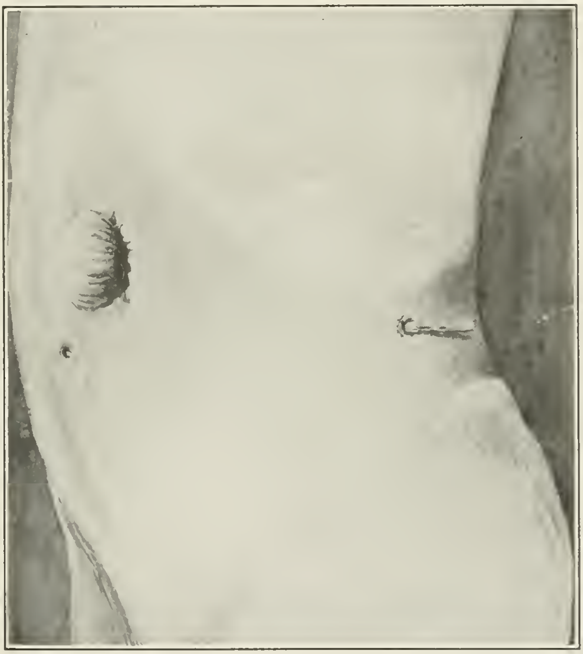


Fig. 122.—Knuckle of gut from wound of entrance and omentum from wound of exit in Thornburg case.

a most careful search after removing the bowels from the body. Other cases might be quoted, but this one is enough to establish beyond doubt the possibility of a bullet traversing the abdominal cavity below the umbilicus without wounding the small intestine."

From the foregoing it may be taken for granted that when a bullet traverses the intestinal area without the appearance of symptoms of peritonitis the small intestine has escaped perforation.

(4) **Perforating Gunshot Wounds of the Abdomen.**—In this class of wounds the peritoneum is not only opened but there is lesion of some of the contained viscera.

Pathology.—The wound of entrance is more often located on the anterior surface of the abdomen and this is especially true of wounds met in civil hospitals from personal combat. Less often the wound of entrance is located on the flank or back. In military practice a projectile often enters the peritoneum after traversing distant anatomical parts. Bullets from high-power military rifles frequently enter the buttock, neck or thorax, and subsequently cause perforating abdominal wounds.

Protrusion of the omentum or intestine is common from shell wounds and the wounds of the military rifle at proximal ranges. Protrusions are apt to occur also from the larger calibers; they rarely occur as a result of wounds from the present-day military bullets at the battle ranges.

Referring to the order of frequency of wounds of the abdominal contents, the small intestines which occupy most of the target area rank first, next in frequency come the liver, stomach, large intestine, kidneys, spleen, and pancreas.

The "Deutsche Kriege Sanitäts Bericht found in 192 cases:

93	injuries to the intestine,	48.43+ per cent.
68	injuries to the liver,	35.41+
16	injuries to the stomach,	8.33+
2	injuries to the spleen,	1.04+
13	injuries to the other organs,	6.77+

Stevenson found in 161 cases:

40	injuries to the colon,	24.84+ per cent.
35	injuries to the small intestines,	21.73+
28	injuries to the liver,	17.39+
17	injuries to the bladder,	10.55+
14	injuries to the spleen,	8.69+
13	injuries to the stomach,	8.07+
13	injuries to the rectum,	8.07+
1	injury to the pancreas,	.62+

The American Sanitary Report found among 1092 cases:

673	injuries to the intestines,	61.63+ per cent.
173	injuries to the liver,	15.84+
79	injuries to the stomach,	7.23+
79	injuries to the kidney,	7.23+

54	injuries to the blood-vessels and peritoneum,.....	4.94+
29	injuries to the spleen,..........................	2.65+
5	injuries to the pancreas,......................	.45+

Bullets from military rifles travel in a straight line from the point of impact to the point of exit or lodgement, and the organs located in the bullets path are usually perforated. In civil practice, and in the days of low-velocity weapons, balls were known to pursue an erratic course. The literature on the subject of glancing balls from the resistance encountered in fascia, tissues like bone, tendons, etc., appears incredible to us to-day, and such occurrences are no longer considered possible with the use of the more perfect modern firearms. The surgeon is therefore justified in estimating the lesion in a given case to include the structures in the path of the bullet as determined by the location of the apertures. This statement contemplates due consideration of the position of the individual at the time of injury.

The character of the lesion in the abdomen largely depends on the factors of velocity, sectional area and resistance on impact. The latter is especially variable in this anatomical region, depending as it does on the amount of fluid contained in the intestinal tube when hit. As already pointed out in preceding chapters, there are two things in the body which offer maximum resistance to the bullet, viz., compact bone and water. The degree of traumatism in muscle tissue at a 5-foot range, for instance, for the present service rifle is not much beyond 17 mm. If, however, the ball should make an impact at the same range upon the intestine or stomach when these organs are loaded with fluid contents, the resistance encountered by the maximum velocity would result in extensive lacerations and shock, which would end in death at once or very soon thereafter. If the intestine is but partially loaded the lesion will be correspondingly less, and if it lies empty the amount of destruction will be no less than we find in other soft parts, like muscle tissue. In the case of the latter the amount of destructive effects would be measured more by the sectional area of the bullet. Wounds from a .45-caliber bullet as an example would be correspondingly more lacerated and contused than those from a .22-caliber Flobert rifle, or the projectile of the reduced-caliber rifle.

The size and character of the wound in a hollow viscus si also influenced by the angle of impact. Wounds from shots transverse to the gut are smaller than those disposed in an oblique direction. The redundance of the mucous membrane over the serous coat also influences the size of the opening and liability to escape of gas and fluid

contents in the peritoneal cavity. Perforation of the small intestine is followed by eversion of the edge of the mucous coat and in small perforations like those of the .30-caliber military rifle, this occurrence may go far to explain the unexpected recoveries that have become so common in recent campaigns. This hernia which is said to be due to the redundance of the mucous coat and further to contraction of the circular muscular fibers is not so apt to occur in wounds of the stomach or colon.

Wounds of the intestines per se are not prone to hemorrhage unless the lesion is located at the mesenteric border. On the other hand wounds of the mesentery proper, the omentum, and solid viscera are very apt to be followed by bleeding. The cutting effects of reduced-caliber jacketed bullets are specially exhibited in injury to vessels in the abdomen and doubtless this class of wounds figures quite a bit in swelling the mortality list on the field in the wars of to-day. Hemorrhage on the whole is one of the most frequent causes of death in abdominal wounds. Its occurrence is aggravated by the engorgement of the internal organs when reaction from shock is about to take place.

Extravasation from the stomach, the urinary and gall bladders has an important pathological significance. Wounds of the latter two are usually followed by discharge of their entire contents while a wound of the stomach is only accompanied by partial extravasation when the wound is sufficiently large.

Extravasation takes place immediately when the wound is manipulated and if the opening happens to be large. Even in extensive wounds Douglas[1] states that extravasation occurs less frequently in the first few hours than is generally supposed. Eversion of the mucous membrane and arrest of peristalsis during the first twenty-four hours are chiefly concerned in preventing extravasation. Should peristalsis be resumed the mucous membrane is retracted, and if the exudate is insufficient extravasation takes place.

Wounds of the mesentery find their chief pathologic interest when the projectile cuts a vessel. Hemorrhage threatening life at once, or gangrene later, is the chief danger. The latter is especially prone to occur in wounds at the mesenteric border.

The facts to be remembered when in the presence of a gunshot wound of the abdomen are:

(1) The outcome is problematical.

(2) The exact lesion is uncertain.

[1] Op. cit.

(3) All wounds are septic from (a) the clothing, (b) skin, (c) the projectile and (d) extravasation when present.

(4) Complications are uncertain.

(5) When the abdominal cavity has been penetrated, visceral perforations are present in 97 per cent. of the cases.

(6) A bullet crossing the intestinal area may do so without perforating the gut, but the occurrence of perforations is the rule. As many as twenty-eight perforations have been recorded in one case. Multiple perforations occur mostly in the ilium from transverse and oblique shots disposed from flank to flank.

The outcome will depend upon the nature of the injury, the amount of hemorrhage, the character of infection and the presence of extravasation from the intestinal track, the biliary and urinary passages. A small hemorrhage may be absorbed, large hemorrhages unless they prove immediately fatal are prone to undergo septic changes ending in peritonitis. Effused blood is at times walled off by plastic lymph and then absorbed, otherwise pus formation takes place. The development of perforation peritonitis in cases of intestinal perforation is the rule in the course of twelve to twenty-four hours. Virulent infections have been known to cause death before the appearance of the characteristic changes incident to peritonitis.

General Symptoms.—Constitutional shock is the first symptom to attract attention. It is not always present, however, and it may be present in profound degree in cases where the peritoneum has not been involved, a fact which tends to lessen its importance as a symptom with diagnostic features. It is generally admitted that the importance of shock as a symptom rests on its duration.

Vomiting is a pretty constant attendant symptom of penetrating wounds of the abdomen, but it may be due to shock as well. Vomiting of blood is indicative of gastric perforation but not necessarily so. It may occur from contusion.

Pain at first of a colicky and griping nature about the region of the umbilicus is a fairly constant symptom of lesion of the small intestine (Parker and Myer). Later the pain radiates to the chest and groins and generally over the abdomen.

Tympany occurring suddenly from escape of intestinal gases sufficient to efface liver and splenic dullness was evidently common with the use of larger-caliber bullets because Otis refers to it as one of the important symptoms. The use of smaller calibers and the subsequent hernia of the mucosa in the small opening has the tendency

to prevent the escape of gas because Treves and other observers in recent times lay no stress upon it as a sign of diagnostic value. It is a prominent symptom of intestinal perforation in later complications and perforations.

Emphysema occuring in the cellular tissue about the wound is a rare symptom. It is not a definite sign of intestinal perforation although it does occur after wounds of the colon from colon bacillus infection.

There are certain signs which are regarded as positive evidence of intestinal perforation:

(1) Escape of intestinal gas, feces or intestinal worms from the wound of entrance or exit.

(2) Protrusion of the injured gut at wound of entrance or exit.

(3) Passage of the missile or blood by the anus.

Escape of gas and feces and protrusion of the intestines were common enough symptoms from wounds by the old armament and they are common with the use of present-day projectiles when the injury exhibits explosive effects or from wounds inflicted by shell fragments and shrapnel. Escape of intestinal worms is rare, except among peoples in tropical countries where intestinal parasites are to be found in the intestines of all natives. Four worms were found making their way in the peritoneal cavity in one of the author's cases in the Philippines fourteen hours after the injury, and the small intestines were everywhere inhabited by the ascaris lumbricoides. The great difficulty with the more certain signs of intestinal lesion lies in the fact that they are either absent or late in making their appearance. Passage of red blood from the anus indicates lesion of the colon or rectum, but as stated already it is one of the later symptoms. Dark bloody stools indicate lesion of the small intestine. Its escape from the anus is in the form of a dark semifluid mass (melena), but it does not appear until re-establishment of peristalsis which occurs too late to make the symptom of diagnostic significance to the surgeon.

Diagnosis of perforation has often to be inferred from a study of the location of the apertures made by the ball and the various anatomical structures which normally lie in the bullet's path. In the days of low-velocity projectiles much was written of the erratic course of balls. It is said that missiles often took circuitous routes from the point of entry to the point of exit on impact against hard and soft tissues alike. Much of this sounds like fable now. As we understand the mechanics of projectiles to-day, we recognize no angles, nor devia-

tions to occur from the point of impact to that of exit. We regard the idea of a modern bullet deflected dy the skin, fascia, or a knuckle of intestine as mythical. We figure that everything in the line of flight of a bullet is perforated and the surgeon who relies on this idea is seldom wrong.

Doctor Senn once advocated the so-called hydrogen gas test to detect intestinal perforation, but this method in diagnosis is unreliable and it takes valuable time.

The diagnosis of the exact lesion is not so important as the diagnosis of penetration of the peritoneal cavity itself, and that must be inferred from the position of the wounds and the direction in which the bullet was travelling at the moment of impact. Whether the small intestine is injured or whether it is the large intestine does not matter. It is all guess work at best until the abdomen is opened. The most that we can say is that wounds in the umbilical region are apt to be attended with lesion of the small intestine, wounds disposed transversely from flank to flank are apt to be complicated by lesion of the colon; those located above a line drawn across the umbilicus and below the costal margin are more often attended with lesion of the transverse colon and stomach, while wounds disposed obliquely may implicate large and small intestines and some of the solid viscera as well. Escape of hard fecal matter from the external wound suggests lesion of the large intestine and if the fecal matter be fluid the evidence points to lesion of the small intestine. Dark blood in the stools occurs with lesion of the small intestine, while red blood indicates lesion to the large gut.

Prognosis and Fatality of Perforating Gunshot Wounds of the Abdomen.—The gravity of this class of wounds ranks with that of wounds of the head and spine. It was especially so with the use of the old armament. Penetrating and perforating wounds of the abdomen regardless of the viscera involved gave a mortality of 92.5 per cent. in the Crimean War; 90 per cent. in our great Civil War; 69 per cent. in the Franco-German War; an average of 67.1 per cent. in 115 cases in the Spanish-American War and Philippine Insurrection; and approximately 56 per cent. for the Russian wounded in Manchuria.

Shock from extensive lesion of the abdominal contents is a potent cause of death on the field. Impact at close range from the high-power military rifle bullet, especially when the digestive tube is filled with semifluid contents, causes wounds with explosive effects that prove rapidly fatal. The wounds which favor hemorrhage and shock seldom reach field or base hospitals, they are uniformly fatal in a

very few hours, and they occur amid environments which preclude laparotomy.

At the same time that the reduced-caliber bullet, impressed with maximum energy, proves so deadly as in the foregoing class of cases, there are other cases occurring at mid and more remote ranges which live to reach field hospitals with but few of the marked symptoms of perforation. The large majority of these are followed later by the sudden development of fatal septic peritonitis. There is still another class in which the location of the wounds points strongly to the presence of visceral lesion, with but slight symptoms of perforation. These cases are apt to end in recovery and they form a surprising percentage of the cases in the field hospitals of recent wars. This was the class of cases that stood out as a puzzle to the surgeons of the 5th Army Corps at Santiago who were among the first to recognize the divergence that lies in the pathology, prognosis, and the necessity for surgical interference, between cases of abdominal wounds in military and civil hospitals.

TREATMENT OF PENETRATING AND PERFORATING GUNSHOT WOUNDS OF THE ABDOMEN

Whether the contained viscera have been perforated or not the treatment of gunshot wound of the abdomen at the onset is the same. This may be divided into general and operative measures. The general treatment consists in absolute rest on the back with shoulders raised and the knees flexed. The latter will materially add to the comfort of the patient. Transport for any distance should be withheld. If necessary to remove the patient, even on a stretcher, this should be done with great care. The patient should himself remain absolutely passive in any effort to move him. All fluids, food or medicines per os should be interdicted for thirty-six to forty-eight hours. Thirst may be relieved by injections of warm water per rectum. Shock may be combated by strychnia hypodermically and stimulants per rectum. The external wounds should be dressed antiseptically. For cases occurring on the field painting the skin about the wound with tincture of iodine preceding the application of a first-aid dressing is preferable.

When operation is not to be practised, opium should be administered in the form of morphine hypodermically to control pain and peristalsis. In cases which lend a hope of recovery opium will form the sheet anchor of the treatment, and in those which appear hopeless it will ameliorate suffering.

The question of operation has received much attention in recent times especially from surgeons in civil practice. Since the great advances in abdominal surgery, the question of operation in military practice was never prominently brought to the attention of military surgeons until the Spanish-American and Anglo-Boer Wars. At the same time that it was the rule in civil hospitals to operate in all cases as early as possible, the U. S. Army surgeons were among the first to recognize that the rule of our civil confrères could not be followed in military practice and this view has since been accepted by military surgeons in all countries. Incidentally the failure of military surgeons to follow the lead of men in civil practice has enabled the profession to observe what may be the outcome in cases that are let alone, and as we hope to show later, the results in the practice of military surgeons in recent wars have had their influence in modifying the views of operators in civil life.

Surgeons in civil practice were and many are still of the opinion that early laparotomy with a view to exploration and the performance of such surgical attention as existing lesion might demand offer the best chance for recovery. Their conclusions were based upon statistics of non-operated cases in the pre-operative era which are quoted in all of the literature and which run about as follows: for every 100 cases of gunshot perforation of the abdomen the intestines will be perforated in 73.2 per cent. and death is the rule in all cases. Either the intestines or solid viscera or both will be injured in 99.8 per cent. of the cases and for these death is the rule in nearly every case in a few days or weeks, as a result of septic infection or abscess. If these statistics are correct there is no doubt that surgeons of skill in abdominal work, under favorable environment were, and still are, justifiable in following the rule of an early operation in all cases.

Doctor W. E. Parker[1] has shown that when cases are treated by laparotomy, those exhibiting wound of the solid viscera give a mortality of only 61.6 per cent., while of the class involving both solid and hollow viscera there is a mortality of 62 per. cent. Parker further shows that the mortality rate rises as the time of operation is delayed and that of the cases showing wound of the hollow viscera operated upon within the first seven hours the mortality falls as low as 47 per cent. The hope of recovery in those operated upon between seven and fourteen hours declines rapidly and all hope is practically lost after the lapse of twenty-four hours.

[1] Proceedings Southern Surgical and Gynecological Asso., Vol. XI, 1896.

Dr. Ernest Siegel[1] points out that the death rate in 532 non-operated cases was 55.2 per cent.; and 51.6 per cent. in 736 cases subjected to operation. This tabulation was made in 1898 for cases occurring from weapons used in civil life prior to that time. The results favor treatment by operation by the small margin of 3.6 per cent. For those operated upon within the first four hours the mortality is only 15.2 per cent., while of those operated upon after twelve hours the mortality is 70 per cent.

Fenner[2] gives a series of 105 cases with visceral perforation subjected to operation with a mortality of 73.95 per cent.

Richard Douglas[3] collected 65 cases operated upon in the literature between 1895 and 1900 not included in Siegel's cases, with the surprisingly low mortality of 32.3 per cent.

In the Spanish-American War we had surgeons of recognized ability from civil life who accompanied the army at the front. Among these were Professor Nicholas Senn of Chicago, with the rank of Lieutenant-Colonel of Volunteers, Major Charles Nancrede, U. S. Volunteers, Professor of Surgery in the University of Michigan, and Doctor W. E. Parker, Acting Assistant Surgeon, U. S. A., of New Orleans, just referred to. Doctor Parker's impressions of gunshot wounds of the abdomen by the Spanish Mauser under the conditions that obtain in active campaign are set forth in a paper read before the Southern Surgical and Gynecological Association at its annual meeting 1898–99. He mentions the three laparotomies which were done at the front with fatal results and cites cases in which he had the opportunity to perform laparotomy himself and where he advised against operation because of "the small caliber of the bullet, the difficulty in getting hot water, and the absence of trained assistants. Then, too, it is a good deal of a question if, in the congested condition of an army hospital after a battle, we would be justified in taking the time necessary for such an operation to the detriment of other wounded men." In concluding this paper he advised against operative interference on the field except in the presence of internal hemorrhage. After Doctor Parker had read a paper at a previous meeting in 1896 on Penetrating Wounds of the Abdomen, before the same Society, a lengthy discussion took place on the management of gunshot wounds of the abdomen in

[1] Siegel, Beiträge zur klin. Chirurg., XXV, 1898.

[2] Fenner. Annals of Surgery, Vol. XXXV, 1902.

[3] Richard Douglas, Surg. Diseases of the Abdomen, P. Blakiston, 1909.

which some of the leading surgeons of this country took part. The views of the members were so generally unanimous in favor of early operation that the Association then and there adopted a resolution which proclaimed it to be the sense of the Southern Surgical and Gynecological Association that in all cases of penetrating wounds of the abdomen it became the duty of the attending surgeon to make an exploratory incision and that when found necessary the repair of existing lesions should be practised. This was the doctrine advocated prior to the Spanish-American War by surgeons in civil life generally. Naturally when Doctor Parker read his second paper, after the battle of Santiago, in which he advocated "that abdominal work should not be attempted in the field unless there are symptoms of hemorrhage," some of his confrères thought that he had receded from his position of three years before, but in the discussion which followed the reading of this paper, he took occasion again to express his former convictions on the value of early operation in civil hospitals in which he stated that laparotomy was the first thing to do.

The hesitancy which Doctor Parker and all our surgeons expressed at the battle of Santiago toward laparotomy has been voiced by surgeons in recent wars generally. Treves, MacCormack, Watson Cheyene, Makins and Stevenson in the Anglo-Boer War admit the value of the rule to open the abdomen early in civil practice, but they are unanimous in advising against operation in active campaign because of the want of trained assistants and the unfavorable conditions that obtain to properly secure aseptic work, and because so many of the cases get well without operation.

Mr. Makins, writing from the standpoint of a civil surgeon upon cases in which penetration had occurred in the central area around the umbilicus in the South African campaign, states as follows: "The surgeon will often find himself surrounded by difficulties, so hand-tied by the overcrowded state of the field hospital and want of all but the most inadequate means of even aseptic work, that he may feel himself compelled to refrain from interfering, while he knows that under other circumstances operation might give the patient a chance of life."

As to the experience of army surgeons in the Russo-Japanese War, they took the field fully advised of the untoward experience of the American and English surgeons. Nevertheless, the reports show that on both sides, the Russian and Japanese surgeons did laparotomies in the beginning of the campaign. Major Charles Lynch, Medical Corps,

U. S. A.,[1] our attaché with the Japanese army, states that abdominal wounds were universally treated on the expectant plan by the Japanese surgeons, and speaking of field environments he says "it would have been absolutely unjustifiable, however, for either the Russian or Japanese to have operated with the conditions as they existed." In the early part of the war he saw laparotomies performed but the results were so discouraging that the operating surgeons had to desist in the same way that some of our operators were commanded to desist from operative interference on the line at Santiago.

Follenfant, a French Medical Officer with the Russian army saw some successful laparotomies performed in a specially prepared operating room on a hospital train inside of three hours after the injury, otherwise the success attained in primary laparotomies was bad. He states that in the hospitals at the rear, partial laparotomies for the evacuation of abscesses consequent upon localized peritonitis were frequently performed with success. To us this is additional evidence of the number of cases of gunshot wound of the abdomen by the new military rifle that recover without fatal septic peritonitis. As a matter of fact Follenfant was strongly impressed by the beneficence which resulted from the use of small-caliber bullets in this war. He saw men who were cured and restored to duty after apparent gunshot lesion of the intestine, without operation. But he adds that penetrating gun-shot wounds of the abdomen by shrapnel balls were generally fatal.

Another of our attachés, Col. Valery Havard, Medical Corps, U. S. A.,[2] saw twenty-five cases of gunshot injury of the abdominal cavity. "No operation was possible or attempted." Some of the wounded had been transported forty miles in carts over rough roads, and also on horseback. Seven died. Eight developed peritonitis. These happy results were no doubt obtained from the slightly wounded —cases in which the viscera were but slightly injured, where the hollow viscera were probably not perforated and if perforated the narrow perforation was more than likely occluded by hernia of the mucosa.

The cases reported by Bornhaupt,[3] who was attached to a Red Cross Hospital on the Russian side in the Manchurian campaign, give

[1] War Department, Office General Staff, No. 3, Jan. 1, 1907.

[2] War Dept. Report Gen'l Staff, No. 3, Oct. 1, 1906.

[3] G. S. W. Abdomen, Russo-Jap. War by Leo Bornhaupt, Archiv. für Klinische Chirr., Part LXXXIV.

further evidence of the beneficence which results from gunshot wounds of the abdomen by reduced calibers. It should be remembered that the bullet of the Japanese was the smallest in caliber of the modern military rifle projectiles, being 6.5 mm. weighing about 157 grains. He states that out of all penetrating shot wounds that came to hospital for treatment 89.9 per cent. were inflicted by the jacketed rifle bullet. Out of 162 penetrating wounds of the abdomen three were caused by bayonet thrusts, sixteen by shrapnel and 162 by jacketed bullets.

Those who were received for treatment were shot generally six or eight days before, only a few receiving more than first-aid treatment on the hospital trains to Karbine. Out of 162 cases, 138 showod both wounds of entrance and exit; in twenty-four or fourteen per cent. the bullet lodged; in three instances the patients received two penetrating wounds of the abdomen. He divides the 162 cases into four groups of which the first three required no operation, the treatment was expectant. The fourth group required operation.

In eighty-nine cases of the first three groups there were no symptoms. Out of 115 cases treated conservatively but three died giving a mortality of 2.6 per cent.

The symptoms in the early part of the history of the cases were gathered from statements of the patients themselves. Some showed signs of peritoneal irritation—pains in the abdomen, vomiting and tympanites. After five or six days all these symptoms disappeared. Most of them walked from 2 to 5 miles to the dressing station where a first-aid dressing was applied; some were carried by comrades and some rode on horseback.

In four of the cases the shots were delivered at very close range, while the remainder received the wounds at 30, 40, 50, 200 and 1600 yards. Some of the shots ran transversely, obliquely and antero-posteriorly through the intestinal area.

In all great battles there are no doubt, with the use of the present armament, a certain number of abdominal wounds destined for a favorable outcome, in the same way that a larger number are doomed to die from the beginning. The worst of these die soon after they are shot. The wounds received in the explosive zone belong to this class. Col. J. Van R. Hoff, Medical Corps, U. S. Army,[1] reports that at short range the reduced-caliber bullet of the Japanese when striking the full stomach caused great laceration and bursting of the organ from

[1] War Dept. Report Gen'l. Staff, No. 3, Oct. 1, 1906.

surrounding attachments. Like results were observed with a full bladder, and the solid organs. In these cases death ensues very early from shock and hemorrhage. Hoff testifies to the fatality attending abdominal wounds from ricochet rifle bullets, also from shrapnel balls, and shell fragments.

Captain Eugenio de Sarlo[1] from the recent Italo-Turkish war in North Africa states that laparotomy in the field should be limited to the utmost—to cases in which fatal hemorrhage is taking place. Aside from the fact that laparotomies were generally attended with fatal results, too many wounded required the precious time that must be devoted to the comparatively few who were hit in the abdomen. Instead of laparotomy the Italian surgeons employed hypodermoclyses, subcutaneous injections of morphine, ice bags to the abdomen and the interdiction of food for several days. This treatment gave 55 per cent. of cures according to the reporter and the happy outcome is attributed to the adhesive property of the peritoneum which tends to circumscribe the part injured, and to the defensive action of the omentum, and closing of the small orifice as a result of hernia of the mucosa.

We believe we have written enough upon gunshot wounds in battle to show that there are many among the wounded who recover, and more who die. The former seem surprisingly large because of the large number of wounds which come under the notice of the surgeons at one time, and the statistics of recoveries seem to be especially good because they are gathered from the less serious cases and as already stated because many of the favorable cases result from the use of small-bore rifle bullets at ranges beyond the zone of explosive effects.

From the foregoing it appears that the rule in civil practice has been to operate on all cases of penetrating and perforating gunshot wound of the abdomen, and in military practice in active campaign the rule is to operate only on cases exhibiting symptoms of internal hemorrhage. So far as the practice in active campaign is concerned the rule will have to stand until we can change the unfavorable environments, a thing hardly possible.

As to the rule to be followed in civil practice this, as we have already shown, was based upon statistics of operated and non-operated cases, and the latter made such a poor showing that laparotomy under

[1] Notes on Wounded at Derna by Captain de Sarlo. Caducée, Nov. 16, 1912. Ed. Saval.

favorable conditions was established with apparent reason. In the earlier history of the operative treatment the showing was far more favorable to operation than it has become in recent years. As we have already stated the results of the *laissez-faire* treatment of the military surgeon have awakened the attention of surgeons in civil practice. They are now revising their later statistics and a study of these make it a question if operation in all cases is the proper rule to follow. In approaching this subject of the treatment to be adhered to in civil hospitals we have to remind our civil confrères that military statistics for their purpose are very much one-sided. We only take cognizance of the cases which reach hospital care and they are those for the most part that have survived a number of hours already—they are the cases which have survived shock more or less and that have not died of internal hemorrhage. If our statistics were made up from all the cases as they are in civil life, and if these cases were all operated upon as they generally are in civil hospitals, the percentage of mortality of our operated cases would be enormous, because the character of the wounds in those that die soon after they are hit by rifle bullets—in the explosive zone—and from pieces of shells and shrapnel balls, are doomed to die under any method of treatment.

We have collected the results in 144 cases of penetrating gunshot wounds of the abdomen from the Annual Reports of the Surgeon General, U. S. A., from 1898 to 1910 inclusive. Of this number fifty-eight cases were treated by laparotomy with a mortality of 67 per cent.; and eighty-six cases were treated expectantly with a mortality of seventy per cent. Doubtless many of the cases treated expectantly were so treated on account of the gravity of the injuries or because of the unfavorable surroundings for operation.

Twenty-nine of the laparotomies were reported for the years 1898 to 1902 which corresponds to the years of active field operations during the Spanish-American War and Philippine Insurrection. The cases were operated upon no doubt mostly under the unfavorable conditions that obtain in war. The mortality for this group is 71 per cent. The remaining twenty-nine laparotomies were done between the years 1903 and 1910, which corresponds to garrison conditions in which the surgeons have access to fixed hospital accommodations and for this group the mortality is 62 per cent. Compared to results which we will show later these results are in keeping with those in other armies for field conditions, and the garrison cases compare favorably with those in some of our large civil hospitals.

The missiles inflicting the wounds in the 144 cases are not sufficiently well designated to give any idea of their caliber or composition. One hundred and twenty of the wounds were inflicted by bullets, two by shells, three by shrapnel, one by lantaca slug, and eighteen not stated. We may take for granted that the majority of the wounds caused by bullets resulted from steel-packed reduced-caliber bullets. Quite a number were inflicted by .38-caliber brass-jacketed Remington rifle bullets. Beyond that, the nature of the projectiles cannot be definitely stated, which gives an indefinite idea of the nature of the wounds. In reporting gunshot injuries practitioners should be more specific in describing the nature of the projectiles. This is a fault common to both military and civil practitioners. Surgeons generally should be impressed with the fact that there are gunshot wounds and gunshot wounds. That the character of the lesion in a given case and the prognosis thereof is largely influenced by the velocity and the sectional area normally present in the projectile and what may be acquired by deformation.

Later statistics from civil hospitals and individual practitioners tend to show that a series of non-operated cases nowadays does better without operation. Dr. Rudolph Matas of New Orleans was kind enough to look over the statistics of Charity Hospital in that city, where so many cases of gunshot wounds are treated annually. He informs us that according to Doctor T. G. Richardson in the five years preceding May, 1887, in the time when operative treatment was not employed, the mortality for non-operative cases of penetrating gunshot wound of the abdomen was 59.4 per cent. This can be taken as a basis for the chance of recovery by the expectant plan of treatment from gunshot of this region by projectiles from pistols and revolvers of low velocity and moderate calibers so much used in civil life at about this time.

The first group of cases operated upon at this hospital was by Doctor A. B. Miles, who reported thirteen cases in 1893, with a mortality of 60 per cent. The percentage of recoveries was 40 per cent., which is practically the same as in those not operated and reported by Richardson, viz., 40.6 per cent.

Later, in 1896, Doctor W. E. Parker, assistant surgeon of the hospital, operated thirteen times with 53.8 per cent. mortality, 46.2 per cent. recoveries.

Later, Matas and Hynes (not published) compiled all cases for the decade 1890-1900 treated by the Surgeons of Charity Hospital:

	Cases	Deaths	Mortality
Operated	122	84	68.85 per cent.
Non-operated	112	60	53.57 per cent.
Total	234	144	61.5 per cent.

which makes the expectant and conservative mode of treatment more favorable by 15 per cent.

For the same hospital Dr. E. D. Fenner (Annals of Surgery, Vol. XXXV, 1902, page 15) compiled 113 cases of penetrating gunshots of the abdomen treated by laparotomy with a mortality of 69 per cent. The mortality was still larger, 73.95 per cent. in cases that were complicated by visceral injury.

In 1905 Dr. H. R. Shands, resident interne of the hospital, wrote a thesis which deals with some of the statistics of the hospital as follows: 150 penetrating wounds of the abdomen were treated in the hospital for the four years Jan., 1901, to Jan., 1905.

Gunshot wounds	Abdomen	Deaths	Mortality
Perforating	118	81	68.7 per cent.
Operated	59	46	77.9 per cent.
Non-operated	59	34	57.6 per cent.

(73.7 per cent. of these gunshot wounds occurred in negroes.)

The injury sustained by the various organs was ascertained in fifty-four of the fifty-nine cases as follows: Intestines were wounded in 79.6 per cent. The stomach in 22.2 per cent. The bladder 13 per cent. The kidney in 3.7 per cent. The spleen in 1.8 per cent. The liver in 5.5 per cent. Perforations of the intestines ranged from one to nineteen in number, and those of the stomach ranged from one to four in number.

In 339 cases of penetrating gunshot wounds of the abdomen compiled by Doctor C. W. Allen for the years 1899 to 1908 inclusive,[1] there were 221 deaths or a mortality of 64.7 per cent. In this series, the

[1] N. O. Med. and Surg. Jour., Sept., 1911.

operated and non-operated cases are included together, and the mortality given is regardless of the plan of treatment followed.

The last series noted is 185 cases for the years 1908 to 1911 inclusive with a mortality of 113 or an average mortality of 60 per cent. As in the preceding series no attempt was made to separate the operated from the non-operated cases.

Doctor Matas who has been connected with this great hospital for many years states that "since 1905 the operative treatment seems to grow less and less in favor in the estimation of the house officers, and the mortality as exhibited in the last five annual reports is practically the mortality of the expectant or non-operative treatment. This average mortality of 60 per cent. for the five years mentioned is almost the same as the mortality which Richardson found for the five years preceding 1887, viz., 59.4 per cent., and which was adopted as an average mortality for non-operated cases. This is certainly far better than the average mortality for the group of operated cases as shown in the following recapitulation:

	Operated cases	Deaths	Mortality
Matas and Hynes, 1890–1900.	122	84	68.85 per cent.
Dr. H. R. Shands, 1901–1905.	59	46	77.9 per cent.
Total	181	130	average 71.8 per cent.

These results, for the operative treatment, certainly form a wide departure from those attained by Dr. W. E. Parker, who was himself a resident interne in Charity Hospital, and who, as already stated on page 243, showed that in the operated cases within the first seven hours of perforating gunshot wounds of the hollow viscera, the mortality was brought as low as 47 per cent. Parker's results are better than Seigle's series, which gave a fatality of 51.6 per cent.; not so good as the latter's cases operated upon within four hours, which was 15.2 per cent., nor Richard Douglas' results which gave a mortality of 32.3 per cent. for all cases.

The figures above quoted for Charity Hospital lead one to believe that the results in gunshot wounds under the operative mode of treat-

ment are worse than formerly. Taking this for granted, what reason can we give to explain the change.

1. Is it due, as some have suggested, to the fact that the laparotomies which were once undertaken by surgeons of mature judgement and prolonged experience in abdominal work are now performed by the house staff, young men, who have no personal experience, and less dexterity, to do an operation with the necessary perfection and rapidity that this, the greatest of all emergency operations known to surgery, requires? or

2. Is it due to a change in the lesion of gunshot wounds to-day as compared to the lesion of twenty or more years ago.

The first of these questions can be answered by the visiting staff of the hospitals concerned, and in order to find an answer to the second question, we know that the change in the character of gunshot wounds in civil practice has been coincident with the evolution in firearms, the same as in military practice.

During the earlier use of firearms in civil life the projectiles from pistols and rifles were round, of large calibers and low velocities. Later conoidal bullets were used, when there was marked reduction in the caliber and weight of projectiles with some addition to the velocity. The crashing effects of conoidal bullets over those of the low-velocity spherical balls is well remembered by surgeons still living. At this stage in the evolution of firearms there came a tendency to retain the smaller calibers with no marked tendency to increase the velocity of projectiles. This was a time in the evolution of firearms that just preceded the use of the high explosives. Bullets from pistols and revolvers of that day —about two decades and more ago—caused wounds the size of their sectional areas with an amount of destruction proportional to the range. The velocity was low compared to that impressed on the bullets of to-day, and there was a great tendency for projectiles to lodge. There were then many patterns of pistols and revolvers in the market, of small calibers, ranging from .22, .32, to .38 calibers, from which wounds were inflicted in personal combat. These weapons were very much used about the time surgeons first commenced to perform laparotomy as a measure of treatment in gunshot wounds of the abdomen. The lesions which they inflicted were not attended with much laceration and contusion. The favorable results in the operated cases were marked, and they attracted the attention of surgeons generally. It then became the fashion to open the abdomen in all cases wherever surgeons could master the environments, for exploratory purposes at least. This

was the status of the subject at the time that the high-power explosives came into use. In Chapter No. 1, on Firearms, Explosives, Projectiles and the Ballistics of the latter, as well as in the Characteristic Features of Gun-shot Wounds as detailed in Chapter II, we have sought to show the changes in wounds from one period to the next.

The introduction of nitrocellulose compounds has conferred marked velocity on lead projectiles of the pistol class, and now that the projectiles for these weapons are enveloped in a jacket of hard steel, as in the so-called automatic pistols, the velocities have become doubled and trebled for this class of hand weapons, with no tendency in the reduction of caliber.

As we have aleady stated in Chapter II, under Wounds caused by Pistols and Revolvers, the effects of this additional velocity on the short, already unstable bullet, has been to render it more so. The projectile loses its balance when encountering the least resistance. It then travels at a tangent to its line of flight, or turns end over end, and, making an irregular impact, it lacerates and mutilates tissues, inflicting conditions most favorable to the development of existing infection. In such a case laparotomy cannot remedy the damage done in the way of hematomata and contusion about the bullet's channel, and the patient is doomed to a fatal issue from the beginning. The instability of the bullet as just mentioned may be likened to the instability that has recently been conferred on the latest projectile of the reduced caliber rifle—the bullet S of some authors, the one recently adopted by this country, England and Germany and described on page 56. We in the military service will witness the same changes in gunshot wounds of the abdomen that the surgeons in civil life are witnessing from automatic pistols and revolvers now. We predict that no observer will ever again say, as Follenfant has said, of the wounds by the 25.5 Japanese rifle, "that the beneficence from the use of reduced calibers in war has even extended to gunshot injuries of the abdomen."

In the recent Turko-Balkan war Major P. C. Fauntleroy,[1] M. C., U. S. A., reports that among the Bulgarian soldiers the large majority of the abdominal wounds died on the field or in a few days from septic peritonitis. The very few that reached the base hospitals required laparotomy for intra-peritoneal abscess. The Turkish army was armed with the German Mauser of reduced caliber, firing the spitz bullet which corresponds to our pointed bullet. Notwithstanding the fact that the Turko-Balkan war referred to was fought with more field

[1] Op. cit.

artillery, and the proportion of wounds by shrapnel is larger than noted in any previous war, we have reason to believe that the spitz bullet has helped materially to swell the mortality among those hit in the abdomen. Between the deadly body wounds of the shrapnel ball and the mutilating effects of the pointed bullet of the military rifle, the future of laparotomy in field surgery is less promising than ever.

Finally we may add that abdomenal wounds in both Civil and Military practise will hereafter be inflicted by very unstable bullets, which travelling at great velocity, will produce ugly lesions that will seldom prove amenable to operative treatment.

In the presence of a penetrating gunshot wound of the abdomen the military surgeon in campaign or civil surgeon in peace must decide at once upon the advisability of operation.

Contraindications to Operation.—(1) A moribund condition, or increasing shock bordering upon profound collapse with impending death, contraindicates surgical aid.

(2) If twelve hours have elapsed since the receipt of the injury the chances of recovery are bad. The surgeons in each case should, however, be the judges of the advisability for operation, using the condition of the patient as a guide.

(3) When symptoms of peritonitis are evident, there is but little hope of recovery from operation.

(4) Unfavorable environments, inexperience on the part of the attending surgeon and his assistants, materially reduce the chance for recovery after operation.

(5) Avoid operation on cases complicated by severe wounds of the chest such as would contraindicate the use of an anesthetic.

(6) It is a question if operation is advisable in cases where the point of entrance is some distance from the mid line of the abdomen, with the course of the ball ranging antero-posteriorly. Still if operation is done under favorable environments no harm can result. In these cases the large intestine has generally suffered perforation. The perforation lies in contact with the parietal peritoneum, the intestine is immobile, and in the case of perforation from small calibers, the intestinal contents being solid, extravasation is infrequent.

(7) When the patient is doing well, as often happens in military practice after gunshot by reduced calibers, eighteen to twenty-four hours after the receipt of the injury, operation should be withheld. Peritonitis more or less localized is present in all these cases, and handling of the inflamed peritoneal surfaces in search of perforations will

do more harm than no operation. Indications for operation in localized peritonitis may show itself later, and when it does the danger from operation is trifling. Again cases that have survived eighteen to twenty-four hours in military practice especially belong usually to that class in which extravasation has failed to take place as a result of the small wound caused by the rifle bullet. This small opening is usually closed by hernia of the mucosa and exudation of plastic lymph, before extravasation has had time to take place; and finally, some of the cases in military practice which have shown negative or trifling symptoms after the lapse of the time above referred to, no doubt belong to the rare class of cases that sustain no perforation, although the small bullet, as already pointed out, may have crossed the intestinal area.

(8) Laparotomy in military practice during active field conditions has proven a failure for a number of reasons. Military surgeons in campaign seldom get the opportunity to operate early. The cases are first seen at the advanced stations where the facilities for abdominal work seldom exist. The lack of water and sterile dressings, the difficulties which arise from proper shelter, and an equable temperature under canvas in all seasons of the year, as well as the difficulties that arise from wind, dust, flies, etc., all combine to preclude aseptic work, under field conditions. When the wounded finally reach the field hospitals where facilities for abdominal work are to be found, the time for safety in operation has gone by, and if it has not, the surgeons are so occupied in doing necessary work on a great number of other wounded that common justice to the greater number does not permit the employment of a large operating staff, with the necessary time and personnel, to be detached to do abdominal work on a comparatively few wounded.

Indications for Operation.—(1) Protrusion of the intestine from the wound soiled by dirt and feces, when the patient's condition permits, demands immediate operation, even though the surroundings are not entirely satisfactory.

(2) When the symptoms indicate that internal hemorrhage is going on, the chance of saving life by laparotomy and the ligation of bleeding vessels should be undertaken though the environments are precarious.

(3) When a bullet has crossed the intestinal area, if the time after the injury and the environments permit, laparotomy should be done promptly.

Operation: Having determined by the condition of the patient and the nature of the injury that abdominal section is necessary the patient should be anesthetized with ether preferably. A median incision giving ample room should be made in all cases in which the ball has entered near the mid line and in which the track of the bullet has crossed a median plane. When the course of the ball is well established and located laterally the incision may be made over the corresponding side. Upon reaching the abdominal cavity bleeding should be promptly arrested by ligation, or pressure with a gauze pad. The extravasated blood should next be removed from the peritoneal cavity by sponging.

Intestinal perforation should be closed by suture at once if small, and when large the lumen above and below the perforation should be clamped with rubber-covered forceps for the time being. The method of repair of the latter and all visceral injuries will be dealt with under appropriate headings later.

Drainage should be employed wherever the lacerated condition of the tissues tends to cause necrosis, and whenever bleeding surfaces require the application of pressure by tamponade. The latter is preferable to the actual cautery, which should be avoided.

Stimulation by strychnia sulphate hypodermically, and the use of salt solution with adrenalin, should be employed whenever the patient's condition demands it.

Wounds of the Small Intestine.—In point of frequency wounds of the small intestines take precedence over the rest of the abdominal viscera. As we have already intimated the small intestines make a marvelous escape in a certain percentage of antero-posterior shots, but it may be laid down as a rule that transverse and oblique shots, through the abdomen in the vast majority of cases cause multiple perforations of the intestinal tube. As many as twenty-eight perforations have been thus encountered. Free extravasation of fluid fecal matter is favored by the number of perforations. Some of the latter are slit-like tears, which occur in the long axis of the gut. The tendency to the early development of septic peritonitis is almost invariable. In penetrating wounds of the abdominal cavity the small intestines are said to be perforated in 65 per cent. of the cases and death will take place in percentages which will vary with the character of the lesion, and the latter, as we have already stated, depends largely upon the sectional area and velocity of the projectile. Peritonitis and internal hemorrhage are the common causes of death. Perfora-

tions from small calibers are usually closed by hernia of the mucosa. The escape of the contents is further aided in some cases by arrest of peristalsis and the presence of plastic lymph, which is thrown out in a short space of time. The hernia caused by the everted mucosa may occlude the perforation so perfectly that hemorrhage will find no access to the lumen of the gut, so that in cases of multiple perforation there may be little or no blood in the stools. Wounds of the mesenteric border favor the presence of hemorrhage. Injury to the blood supply of certain areas of gut, as occurs, for instance, in shots through the mesenteric border without perforation of the gut, is apt to end in gangrene. Perforative septic peritonitis usually develops, in the first few hours. Depending upon the virulency of the infection, death will occur in thirty-six to forty-eight hours in the large majority of cases.

The tendency to hemorrhage, or the development of peritonitis, depends largely upon the character of the wound. Wounds by small calibers, animated by low velocity, are prone to local peritonitis or recovery. No doubt many of the soldiers who recover so unexpectedly in military practice owe their lives to the small perforations that result from projectiles of reduced-caliber rifles with low remaining velocities. Surgeons in civil life get their best results in operated and non-operated cases from wounds inflicted by the smaller calibers.

Symptoms.—While dealing with general symptoms of gunshot wounds of the abdomen, to which the reader is referred, we mentioned all the symptoms likely to arise from injury to the small intestine. The surgeon should be on the alert for the presence of hemorrhage, as this is the condition next to shock that will require his immediate attention. Unlike shock, it does not yield to remedial measures, and it is not so readily diagnosed. Hemorrhage will not appear externally unless it be in the case of large external wounds. We must look for the presence of fluid in the abdominal cavity as this is revealed to us by physical signs. Areas of dullness which progressively increase about the flanks, associated with persistent shock, indicate that hemorrhage is going on.

Treatment.—The treatment of gunshot wounds of the small intestines requires that all perforations be located by searching the entire length of the gut. To do this properly without overlooking some of the perforations, it is better to commence the search at the iliocecal junction, tracing the small intestine rapidly upward, each loop being carefully returned as soon as examined. Perforations should be closed

as found. Large perforations and injuries on the mesenteric border that call for resection should be controlled by clamps and passed over to be attended to later. Small perforations on the convex border of the small intestine may be closed by continued or purse-string suture. Larger perforations are closed by a line of seromuscular sutures running with the short axis of the gut, and when necessary two lines of sutures, one to include all the coats, and a superficial line to include the seromuscular layer. In much larger perforations the line of sutures should run in a direction coincident with the lumen of the gut provided not more than one-half the lumen is taken up by the suturing, otherwise resection is called for.

Special care is required in dealing with injuries at the mesenteric border lest gangrene of the gut takes place from interference with the blood supply. Injuries involving 1/2 inch or more of the tissue in this location demand resection; any injury less than 1/2 inch may be closed by suture depending upon the judgment of the operator.

Wounds between the mesenteric and convex borders when located nearer the former may at times threaten the blood supply of the convex border. In such cases resection is called for. All suturing should be done with a straight needle threaded with fine silk, six interrupted sutures to the inch will suffice. When resection is done the end-to-end approximation should be accomplished with the Czerny-Lembert suture and in cases where the operator is not experienced or where it is necessary to save time a Murphy button should be used. When two or more resections are to be performed in the course of 2 or 3 feet of gut, it is better to sacrifice all of the intervening gut and bring the ends together by one circular enterorrhaphy, rather than prolong the operation and add to the shock by doing two resections.

Search for perforations in the large intestine is made by using the ilio-cecal valve as a starting point and tracing the gut upward. Closure of perforations to large intestines covered by peritoneum is similar to those in the small intestine, the line of suture with reference to the axis of the gut is not so important, and resections are seldom called for.

After all perforations have been repaired cleansing the peritoneal cavity is next in order. Irrigation is not advisable unless deemed necessary from extensive fouling by the contents of the alimentary canal. Localized extravasations are best removed with moist sponges. If irrigation is necessary, it should be done by flushing the peritoneal cavity with hot normal salt solution.

In all cases it is safer to drain than not to drain. Drainage at the

most dependent point is specially indicated in cases likely to be followed by coagulation necrosis and those where extravasation has been marked.

Gunshot Wounds of the Stomach.—Wounds of the stomach were very fatal in the days of the old armament. Aside from the dangers of sepsis, the wounds of that day were large and there was always danger of free extravasation of the irritating stomach contents with resulting peritonitis, and, as the records show, great tendency to subphrenic abscess.

In the distended state, the relation of the stomach wall to the parietes makes it an easy target for perforation. In point of frequency wounds of the stomach come after those of the intestine and liver. There were sixty-four cases treated in our hospitals during the Civil War, but on account of the fatal character of complicating wounds to adjacent organs, this number only represented a fraction of the wounds of the stomach received in action.

In recent wars uncomplicated wounds of the stomach have frequently ended in recovery. This has been attributed to the empty condition of the organ which so often obtains among soldiers in active campaign, the thickness of the stomach wall, and the narrow channel made by the bullet. Stevenson mentions twelve cases in the Anglo-Boer War with two deaths, one as a result of peritonitis and the other from hemorrhage. Follenfant states that the statistics at Kharbine in 1904 gave forty-two deaths out of 252 penetrating wounds of the abdomen, with lesion of the stomach and intestine.

Wounds of the stomach are apt to be complicated by the presence of other wounds such as those of the left kidney, spleen ,liver, pancreas, transverse colon, diaphragm and thoracic viscera.

The prognosis as reported by different authors is variable. Laplace[1] has found gunshot wounds from small calibers to end in recovery in the majority of his cases, while MacCormac[2] states that 99 per cent. of gastric perforations end in death.

The prognosis of uncomplicated stomach wounds will largely depend upon the character of the wound as influenced by sectional area, velocity, and resistance on impact. Wounds inflicted by the high-power rifle at proximal ranges will show explosive effects in accordance with the amount of fluid in the viscus. All wounds showing explosive effects are rapidly fatal.

Repair of Injury to the Stomach.—Wound of the stomach should be

[1] Sajouss' Annual and Analytical Cyclopedia of Prac. of Medicine, Vol. I, 1899.
[2] Tillman's Text-book of Surgery (Tilton), Vol. III, 1898.

closed by Lembert suture in the direction of blood vessels. If the wound is large the Czerny-Lembert suture is preferable. Wounds of the posterior wall are more satisfactorily reached by breaking through the gastro-colic omentum. When the wound of the stomach is complicated by injury to the pancreas posterior drainage through the skin of the lumbar region should be made.

Wounds oi the Large Intestine.—Gunshot wounds of the large bowel covered by peritoneum, except those of the transverse colon, are never so fatal as those of the small intestine. This was true of gunshot injuries by the old armanent when the lesion was generally more severe than that inflicted by the projectiles of the present day. Otis records fifty-nine cases of spontaneous recovery from gunshot of the cecum and ascending colon, the descending colon and sigmoid flexure, and a few instances from the transverse colon. Nearly all the cases were complicated by fecal fistula which closed spontaneously in the large majority of the cases. Forty-one of the fifty nine cases were still living after the lapse of twelve years or more.

The more hopeful outcome of injury to this part of the intestine is ascribed to the fact that the walls of the gut are thicker than those of the small intestine, and the aperture in them is partially closed by the greater amount of tissue involved in the perforation. In addition the gut is fixed to the wall of the abdomen by the overlying peritoneum, it is therefore immobile, extravasation is not so likely to occur; and again, the contents are usually more solid. It may be stated also that other organs are not so apt to be implicated in antero-posterior shots which penetrate in the line of the ascending and descending colons. In forty cases in the Anglo-Boer War Stevenson fixes the mortality at 32.5 per cent., although some of them had sustained injury to the liver, bladder, and kidney.

Wounds of the Sigmoid Flexure and Rectum.—Wounds of the former are less fatal by far than those of any portion of the intestinal tract. Those of the rectum belong to the hopeful class, when uncomplicated. They are often complicated, however, by shots through the bladder, the adjoining pelvic bones, or femur. Such shots are prone to the development of fecal fistula, cellulitis, and septicemia, the latter being a frequent cause of death. Stevenson records thirteen cases of gunshot wound of the sigmoid flexure and rectum in the Anglo-Boer War with a mortality of 30.7 per cent.

Treatment of Gunshot Wounds of the Rectum, and Colon not Covered by Peritoneum.—Until the Anglo-Boer War gunshot of those

parts of the colon extraperitoneally located were supposed to be attended with less danger to life than the lesions connected with the peritoneal cavity. Mr. Makins, experience is decidedly opposed to this idea. He saw several such lesions every one of which ended fatally and likewise he found that extra- as compared to intraperitoneal wounds of the bladder were also more fatal, to which we will refer later. Like gunshot of the rectum the indications for treatment in colon wounds uncovered by peritoneum are the relief of fistula, cellulitis, and septicemia which result from extravasation of intestinal contents into the tissues outside the gut. Whenever practicable Mr. Makins enlarged the wounds leading to the colon and brought the gut to the surface. The artificial opening in the latter was attended to later. In like cases Colonel Stevenson advises the introduction of 1/2-inch tube as far as the opening in the bowel. Gauze is packed around the tube to prevent the intestinal contents from contaminating the sides of the wound. In such cases the prime indication is the establishment of drainage, and either method when properly carried out should accomplish this end.

In wounds of the rectum colotomy has been advised and practised to prevent the passage of feces into the rectum. Otis calls attention to the fact that the older surgeons recommended and practised division of the anal sphincters to prevent extravasation leading to cellulitis and septicemia, and for the cure of fistulæ that often persist through wounds of the skin in adjoining parts.

Gunshot Wounds of the Liver and Gall Bladder.—Uncomplicated wounds of the liver from small-caliber bullets recover in the vast majority of cases. When complicated by hemorrhage or injury to other viscera the prognosis is not so good. Hemorrhage is probably the most fatal of the complications, and this is proportional to the size of the wound and the liability to injury to the larger vessels in the liver substance. Reporters in recent wars have frequently remarked upon the absence of wounds showing explosive effects in the liver and other viscera in hospital cases. Field hospitals are not the place to look for such cases. They die on the field in a few moments, and never live long enough to receive hosptal care.

Wounds of the liver are often complicated with wounds of the thoracic viscera, stomach, intestine or kidney. The more serious complications are those involving the thoracic viscera and diaphragm. Such cases are very apt to die from pleural septicemia. Wounds complicated by injury to the portal vein are usually rapidly fatal. Those

complicating the gall bladder are apt to cause biliary fistula, and the latter is most frequently seen when the bullet scores the surface of the organ (Makins).

The symptoms, aside from hemorrhage in a certain class of cases, are not typical. One has to be guided largely by the location of the apertures made by the bullet. Icterus occurs in one-fifth of the cases according to Edler.[1] In cases with extravasation of bile in the peritoneum, there is icterus, also cholemia, as evidenced by pruritus, nausea and mental hebetude. Such cases are rapidly fatal unless biliary fistula is established with free drainage.

In the Civil War Otis records fifty-nine uncomplicated gunshot wounds of the liver with twenty-five recoveries. Stevenson reports twenty-eight cases in South Africa with a mortality of 28.5 per cent. and Follenfant gives a mortality of 19.3 per cent. in thirty-one cases in the statistics at Kharbine in 1904.

Gunshot wound of the gall bladder is rarely referred to in the literature, a fact which no doubt testifies to the fatality which attends such cases. The diagnosis has to be made by the location of the external wounds, the occasional flow of bile externally, and active reaction on the part of the peritoneum. The diagnosis is no more than a conjecture until the peritoneum has been opened.

Otis mentions a case which occurred in the Civil War and which ended in recovery. The ball entered on the right side near the cartilage of the tenth rib 3 or 4 inches from the umbilicus, and escaped on a level with the twelfth dorsal vertebra. Seventeen days after the injury, in an effort to sit on the edge of his bed, there was a sudden escape of about 1 pint of bile from the wound of entrance. For seventeen days thereafter about a pint of bile continued to escape daily from the wound. The flow was greatest between the hours of 3 and 6 P. M. The stools were clayey, there was distaste for food.

Treatment.—Gunshot of the liver uncomplicated by hemorrhage requires no surgical interference. This fact is prominently emphasized by the large number of recoveries of gunshot of the liver in recent campaigns. Fischer states that they were regarded among the slight or humane wounds by some of the surgeons in the Manchurian campaign. The impossibility of excluding complications often renders exploratory laparotomy essential. Hemorrhage is preferably controlled by a narrow gauze packing, the end of which should be left protruding through the abdominal wall. In larger wounds when

[1] Archiv. f. klin. Chirurg., Bd. XIXIV, Ch. IV, 1887.

bleeding still continues, the best way to control the hemorrhage is by packing the cavity with gauze, or when practicable the sides of the wound should be brought together by suture. A straight blunt needle armed with number 3 or 4 cat-gut is preferable for the purpose.

When the gall bladder is wounded and the loss of substance is extensive colecystectomy should be practised. In small perforations the wound may be closed by silk sutures or the edges of the perforation may be sewed to the abdominal wall as in colecystectomy.

The following case bears upon the wisdom of early operation and it marks one of the triumphs of the modern method of treatment of abdominal wounds when the surgeon can control the environments.

First Lieutenant Clarence E. Fronk,[1] Medical Corps, U. S. Army, reports the case as follows: "A Philippino woman, fifty years old, was accidentally shot at camp McGrath, P. S., at 5.30 P. M., Oct. 2, 1911, while she was in a stooping posture, facing the gun when it was discharged. The missile was a 32-caliber slug fired from a No. 12 automatic shotgun. She was examined in the post hospital at 11 P. M. when the following condition was noted:

"A wound about 1/8 inch in diameter, 1 1/2 inches below and 1 inch to right of ensiform cartilage. No wound of exit, but the eleventh rib, left side, was fractured at its center and the missile could be palpated just under the skin at this place. The wound of entrance was enlarged, and by exploring with the finger, its entrance into the peritoneal cavity was confirmed. The woman was in a state of collapse, with weak, frequent and thready pulse, and shallow, rapid respiration. Immediately before and during the examination she vomited a large quantity of clotted blood mixed with stomach contents.

"The case clearly demanded surgical intervention and, consent being given by the patient and relatives, she was prepared for immediate laparotomy.

"Sterilization of the operative area was accomplished with 7 per cent. tincture of iodine. The operation was begun at 12.30 A. M., Oct. 3, 1911, under chloroform anesthesia, it not being thought safe to use ether, working as we were with open oil lights.

"An incision 3 inches long was made through the left rectus muscle. Upon incising the peritoneum, the abdominal cavity was found full of fluid blood which welled up from the region of the gall bladder. The latter was located abnormally far to the left; it being directly in the line of incision. The transverse colon was delivered and examined

[1] Military Surgeon, Vol. XXX, No. 6, June, 1912.

and then the stomach. No wound being discovered in either and feeling certain that the latter had been perforated, owing to the patient having vomited a large amount of blood, an opening was made in the transverse mesocolon and the stomach examined posteriorly; but careful search revealed no injury. The liver and gall bladder were then examined and a perforation found in the fundus of the latter from which the blood was flowing freely. This wound was closed with a continuous silk suture, reinforced by a Lembert suture, which effectively controlled the hemorrhage. The patient's condition being extremely poor, a hasty search was made for further injury to the liver, pancreas, duodenum, etc., but none was found. The anesthetic was stopped, the blood mopped out with dry gauze, a quart of hot normal saline solution poured into the abdomen and the wound closed in layers without drainage.

"The entire operation consumed about thirty minutes. Upon removal from the table, the patient's pulse was 140 to the minute and imperceptible at the wrist. She was placed in bed, surrounded by hot water bottles and given 1000 c.c. of normal saline solution into the median basilic vein, to which she responded promptly. Salt solution per rectum by Murphy's method was begun and continued during the following twenty-four hours, taking in all about 3000 c.c. Convalescence was rapid and uneventful, the wound healing by primary union.

"The missile was removed at the end of two weeks and proved to be an irregular shaped 'slug' about .32 inch in caliber.

"The peculiar features of this case are:

"(A) The large amount of blood vomited with no injury to the stomach, the bleeding being from the cystic artery into the gall bladder and then into the stomach by way of the cystic and common ducts and duodenum.

"(B) The possibility of a missile of such a size passing through this region with no injuries discoverable in the other organs and the excessive hemorrhage from the gall bladder wound." The patient's recovery was uninterrupted.

Gunshot Wounds of the Pancreas.—Wounds of this organ have not been frequently noted in the literature. They are usually attended with primary hemorrhage and death occurs early. Its intimate relation with other viscera like the spleen, liver, stomach, duodenum, the large vessels and the spinal column, makes wounds of the pancreas very fatal on the field or soon after receipt of the injury. Otis refers to

five cases occurring in the Civil War. "In one of the cases the ball entered the right side below the ribs and emerged on the left side." Two days later part of the pancreas the size of an egg protruded from one of the wounds. The pedicle of the tumor was strangulated by means of a silver wire and subsequently cut through with scissors. No dangerous symptoms transpired and the patient was up and moving about the hospital at the end of five weeks. Three of the five cases reported by Otis lived from twelve to fifteen days. The causes of death in four of the fatal cases were shock and peritonitis in one, and secondary hemorrhage in the other three. In four of the cases the bullet entered behind and coursed transversely through the body. In one case the ball entered anteriorly near the end of the ensiform cartilage with probable involvement of the stomach. In three of the cases the diagnosis was not made until post-mortem. The autopsies gave but little to note on the morbid anatomy and the clinical histories pointed to no special symptoms referable to traumatism of the pancreas.

Treatment of Gunshot of the Pancreas.—The surgical indications in all wounds of the pancreas are: arrest of hemorrhage and establishment of drainage. The former is to be controlled by suture when possible, otherwise by tampon. Lumbar drainage is always preferable. In twelve cases[1] of gunshot of the pancreas reported by Von Mikulicz-Radecki laparotomy was done in five cases with three recoveries. The seven cases not operated upon died.

Gunshot Wounds of the Spleen.—Wounds of this organ are prone to hemorrhage from the extreme vascularity and friable nature of the tissues. The prognosis is further hampered by accompanying wounds of other organs like the left kidney, the stomach, diaphragm, pleura, lungs and other viscera. The diagnosis usually rests upon a study of the bullet's track. Four cases were diagnosed in the Anglo-Boer War with one recovery (Stevenson). The fact that wounds of the spleen are rare in the literature suggests their extreme fatality. Makins points to a case in South Africa complicated by renal injury. At time of death three weeks later, the wound in the spleen had cicatrized. The same author is of the opinion that wounds of the spleen from reduced-caliber bullets are seldom accompanied by hemorrhage since he never saw a case with dullness in the flanks to indicate the presence of internal hemorrhage. In the cases he saw the diagnosis was made by the location of the external wounds and the bullet-track so that the element

[1] Annals of Surgery, July, 1903.

of mistaken diagnosis has to be considered. Follenfant gives one death in seven cases out of the Kharbine statistics for 1904.

Treatment.—The surgical indications are control of hemorrhage and when this is copious the abdomen needs to be opened promptly. When the bleeding cannot be controlled by suture, splenectomy is to be resorted to.

Gunshot Wounds of the Kidney.—Uncomplicated kidney wounds by gunshot rarely occur. The spleen, intestine, stomach, or colon is usually involved. The lesion may or may not involve the peritoneum. Wounds of the peripheral part of the organ, near the extremities or convex border, offer a better prognosis than those near the central part. If the pelvis of the kidney is implicated, the prognosis is bad, because escape of blood and urine in the peritoneal cavity are prone to set up infection. Extraperitoneal tracks implicating the pelvis or hilum of the kidney are apt to end in perinephritic abscess from extravasation of urine in the surrounding tissues. Urinary fistula is one of the sequelæ of such cases. Fistula persists a long time, but eventually closes spontaneously.

With the use of the old armament the amount of tissue laceration was great and the fatality was in keeping with the amount of lesion. Otis reports seventy-eight cases in the Civil War with a mortality of 66.2 per cent. Wounds of the kidney by the reduced-caliber bullet in recent wars have not been so fatal, especially when the bullet has traversed the extremities or convex border of the organ, away from the pelvis and hilum. At the mid ranges the bullet makes a clean perforation which shows a tendency to heal in a few days, without serious symptoms.[1] Stevenson reports thirteen cases of wound of the kidney out of 207 gunshot wounds of the abdomen, with two deaths. Only two of the cases were uncomplicated. The other organs involved were the spleen 1, stomach 2, large intestine 1, lung 2, liver 1. Such a small mortality, 15.3 per cent., speaks well for the prognosis after wounds of the kidney and other organs as well.

The mortality of the uncomplicated cases is still lower, but we must remember that the greater penetration of the new projectile has a tendency to increase the percentage of complicated wounds and that associated injuries of the lungs, spine, liver, etc., are far more common than formerly.

Injury by shrapnell balls and pieces of shell are prone to hemorrhage and also sepsis, in spite of the improvement in wound treatment, and

[1] Makins, op. cit.

the mortality is but a trifle less than formerly[1] for wounds from this source.

Symptoms.—Pain and hematuria are the two symptoms which specially indicate renal perforation. The pain usually radiates downward extending to the genitals and thighs, and a desire to urinate and retraction of the testicle are present. Hematuria is present in perforating wound of any part of the kidney. It is only absent in cases which have suffered division of the ureter or those cases where blood accumulates in the pelvis of the kidney from which the ureter is occluded. Only clear urine from the other kidney will then reach the bladder. In certain cases with extensive lesion there may be suspended excretion of the kidney with absence of hematuria.

Treatment.—Wound of the kidney generally calls for abdomnial section because the lesion is so often complicated by injury to other organs. When the bullet has severed the renal vessels or committed great destruction of kidney tissue nephrectomy is demanded. As uncomplicated injuries by the modern rifle bullet, wounds of the kidney heal rapidly without serious symptoms beyond transient hematuira (Makins). The treatment in such cases is rest and the administration of opium when hematuria is pronounced. Wound of the pelvis or ureter demands nephrotomy in order to establish temporary drainage for the urine. If the wound is in the loin, free drainage by enlarging the wound should be practised to prevent cellulitis and septicemia from extravasated urine. If hydronephrosis develops it should be relieved by incision and drainage.

The following case of complicated gunshot wound of the kidney treated expectantly on account of the unfavorable conditions in active campaign shows the chance of recovery from gunshot by the new military rifle bullet. Major T. T. Knox, 1st U. S. Cavalry, was shot on June 25, during the advance on Santiago de Cuba. A Mauser bullet entered the back on the right side and ranging forward emerged through the skin opposite the ninth and tenth ribs. He was seen five hours later by Doctor W. E. Parker, who expressed the opinion that the ball had penetrated the kidney and liver. His pulse was 130, "he was in a cold clammy sweat and his urine was full of blood . . . . His condition was such that he would have died on the table had he been subjected to laparotomy. He was given strychnia and atropin under the skin every three hours. At the end of twenty-four hours tympanites developed which disappeared after a full dose of magnesia sul-

[1] Graf and Hildebrandt, op. cit.

phate. The blood in the urine gradually disappeared and the officer was eventually restored to full duty."

Gunshot Wound of the Adrenal Gland.—Injury to this organ by gunshot is necessarily rare on account of its diminutive size as compared to other organs in the body. Otis makes reference to but one case during the Civil War. The ball, after fracturing the ninth rib, penetrating the left lung and diaphragm, lodged in the left suprarenal gland. The man died four weeks later of pyemia. There was a marked icteroid discoloration which it was considered might have been the result of pigment deposit after the bronzing described by Addison. The suggestion is of value in the study of future cases.

Treatment.—No treatment of a surgical nature is indicated for injury to the gland itself.

Wounds of the Urinary Bladder.—Gunshot wounds of this viscus were classed among dangerous wounds in the days of the old armament. The mortality was 63 per cent. in the Franco-German War, 1870–71. Otis refers to 183 recorded cases in the Civil War with a mortality of 54.5 per cent. The majority of those who recovered the immediate effects of the battle injury "suffered from grave disabilities, and many from distressing infirmities." Much of the protracted suffering was the result of fistules from necrosis of the pelvic bones; rectovesical fistulæ and stone in the bladder as a result of lodgment of foreign bodies in the cavity of the organ, such as the projectile itself or fragments thereof, fragments of bone, bits of clothing, hair, particles of integument, and splinters of wood. Our present methods of wound treatment can now forestall the majority of the complications and disabilities mentioned. This, with the beneficence which comes from the use of the reduced-caliber projectiles, has demonstrated that we may expect a favorable prognosis in the large majority of bladder wounds in the wars of the future. Mr. Makins has called our attention to the outcome of extra-peritoneal as compared to intra-peritoneal wounds. In the former there is greater tendency to complications as a result of suppurative cellulitis and septicemia, complications that require active surgical interference. Intraperitoneal perforations exhibit less danger provided the urine is of normal character.

The character of the wound and the prognosis are very much influenced if the bladder is full or empty at the moment of impact. In the latter condition the small jacketed bullet makes a channel which is soon closed by the contractile tissue of the viscus. If, however, the bladder is full the contents escape through the perforations and the

accumulating urine continues to escape. Makins noticed that uncomplicated peritoneal wounds of the bladder recovered spontaneously in a considerable proportion of the cases, but extra-peritoneal perforations were more apt to end in troublesome complications, while all wounds at the base of the bladder died, in his experience.

The superior penetration of the new armament has added to the number of associated wounds that attend injury to the urinary bladder. The bones of the pelvis, the hip-joint, adjoining vessels and nerves, the peritoneal cavity and its different viscera, the ureters, kidneys, genitals, and rectum are often implicated. The order of frequency of wounds of adjoining parts is as follows: bones of the pelvis, intestines, rectum, large blood-vessels, genitals, large nerves, kidneys, ureters.

Stevenson notes seventeen cases in the Anglo-Boer War with three deaths. Two of the cases passed the bullet per urethram. Follenfant gives a mortality of 29.2 per cent. out of fourteen cases in the Kharbine statistics for 1904.

Symptoms.—Hemorrhage and an empty bladder are the two principal symptoms. The latter is generally associated with intra-peritoneal wounds, the urine escaping into the peritoneal cavity, while hemorrhage in the organ is most generally associated with extra-peritoneal injury. The latter are apt to show signs of inflammation from extravasation of urine and later fistula from which urine dribbles. Wounds implicating the bladder and rectum are apt to end in vesicorectal fistula with escape of urine per rectum, or feces and gas may escape per urethram. The appearance of blood in the urine is one of the early symptoms of gunshot wound of the bladder. The bladder is sometimes filled with blood clots which cause retention and infection unless promptly relieved. Abnormal urine escaping in the peritoneal cavity will set up peritonitis very promptly. The course of the ball will often indicate injury to the viscus. The bullet's track is generally disposed antero-posteriorly through or just above the pelvis, but more often it enters one groin and ranging downward and backward it makes its exit through the opposite buttock. Shots implicating the bladder are also disposed transversely just behind the symphysis pubis.

Treatment.—The surgical indications differ in accordance with the character of the wound. Intraperitoneal wounds of the bladder demand laparotomy in all cases in which the environments are favorable for operation. Early laparotomy favors recovery in nearly all uncomplicated bladder wounds. As a matter of precaution the urethra should be cleansed by irrigation with a mild antiseptic solu-

tion after which a sterile catheter is introduced as far as the bladder and secured in place. This is done to distend the bladder in order to bring the perforation into view if necessary, and to drain the viscus in the after treatment.

The perforation in the bladder is brought together by a deep and superficial line of sutures. Urethral siphonage is maintained for forty-eight to seventy-two hours subsequently. We should much prefer to maintain drainage through a perineal section in the regular way as practised after urethral and bladder operations for other causes. The difficulty of keeping a catheter in place in field conditions especially is very great. When the environments are such in field practice that laparotomy is contraindicated, we should recommend perineal drainage, an operation which is easily and quickly done, as the best means of keeping the bladder free of urine. In gunshot from reduced-caliber bullets where the tendency to leakage of urine into the peritoneal cavity is not marked external perineal urethrotomy would establish an additional precaution against extravasation.

Extraperitoneal wounds of the urinary bladder are best treated by keeping the bladder empty. If the external wound cannot be readily drained, the latter should be accomplished by a suprapubic cystotomy or a perineal section and for field conditions, preferably the latter.

GUNSHOT WOUNDS OF THE EXTERNAL GENITAL ORGANS

Wounds of the genitals by gunshot form a comparatively small group of the wounds in war. They were never considered dangerous in themselves when inflicted by the old armament, and they are very much less so now.

The wounds of this class include the anatomical parts concerned, viz., the penis, urethra, testicles and vas deferens.

Wounds of the Penis.—Otis reported 309 cases from the Civil War with a mortality of 13.2 per cent., principally due to grave complications and injuries received elsewhere, as gunshot fracture of the pelvis and femur. Some of the less complicated cases succumbed to diseases like small-pox, tetanus, pneumonia, etc.

Notwithstanding the large-caliber bullets of that day, Otis mentions five cases of lodged balls in the penis, one of the missiles was conoidal in shape and weighed 838 grains when it was removed from the root of the organ, Fig. 123.

The severity of these wounds is necessarily less with the smaller calibers. The wounds of the skin and erectile tissue are of smaller diameter than the projectile. Contrary to what might be expected hemorrhage is not frequent in cases of injury to the large vessels supplying the penis. Hematomata of varying sizes and extent are frequent. Schaeffer mentions a case in which the bullet penetrated the glans and infiladed the penis posteriorly to the bladder when the former was apparently in a state of erection. The more frequent wounds, however, are directed antero-posteriorly or *vice versa*. In some cases the ball enters the neighborhood of the pubis and emerges behind the scrotum while other shots are disposed transversely. The lesion may consist of a furrow, or complete perforation, while wounds from shell fragments have been known to produce entire ablation of the penis.

Fig. 123.—Ball excised from the penis. Spec. 3146 1. Army Medical Museum collection.

Wounds of the Urethra.—The more important wounds of the penis are those which include lesion of the urethra. Otis reported 105 cases in the Civil War with twenty-two deaths. The fatalities like those of the penis proper were often due to severe complications in adjoining anatomical structures. The uncomplicated cases were fatal from "exhaustion," "urinary infiltration," "phlebitis," "dry gangrene," etc., causes that are more often preventable under present modes of treatment.

The amount of lesion to the urethra from the military rifle bullet is not so extensive. The canal may be only partially, or it may be entirely cut across.

The indications are to prevent extravasation of urine in the surrounding tissues which is apt to result from mechanical impediment to the free flow of urine. When practicable the opening in the urethra should be located and a soft catheter should be passed through the opening into the urethra as far as the bladder. If the flow is impeded and retention takes place, suprapubic aspiration or incision should be practised after which the patency of the urethral outlet should be established. Drainage is the prime indication and when-

ever necessary perineal section should be done. Wounds of the urethra from the reduced-caliber bullets in recent wars are said to heal readily with few complications. The occurrence of urethral fistula is treated in the usual way.

Wounds of the Testicles.—Otis records 586 gunshot wounds of the testicle with a mortality of 11.2 per cent. The majority consisted of lacerated wounds of one or both testes with accompanying wounds of neighboring parts like the penis, thighs, perineum, pelvis. The deaths were mostly due to the complicating wounds.

Wounds of the testes are naturally influenced by the size of the projectile and consequently wounds of the testicle and scrotum by the reduced caliber jacketed bullet exhibit small perforations, which heal readily.

Injury to the testicle is attended with more or less shock, vomiting and pain radiating into the abdomen. Hematoma in the scrotum is not uncommon. Should infection result it may extend to the tunica vaginalis and testicle with resulting suppuration.

Treatment of wounds of the testicle consists in a clean dressing and conservative management unless suppuration supervenes when free drainage should be established, but removal of the organ in the majority of the cases with suppuration becomes necessary. In cases exhibiting considerable laceration of the testicle castration should be practised.

Wounds of the Spermatic Cord.—This class of wounds is very rare. They usually consist of contusions, transverse or oblique wounds. Otis records thirty-two cases with two deaths. The published reports from recent wars make but few references to gunshot of the cord.

Hematocele and sanguinous infiltration are usually present with the immediate symptoms. Among the sequelæ, atrophy of the testicle sometimes occurs from injury to the vas, and Otis relates a case in which semen escaped from a fistule located near the tuberosity of the ischium for some time.

The treatment of gunshot of the cord consists in arrest of hemorrhage and a clean dressing.

Wounds of the Scrotum.—Gunshot wounds of the scrotum are seldom attended with much pain or danger. The contractile fibers of the dartos close the wounds so readily that wounds by reduced-caliber bullets are sometimes overlooked. This was particularly noticeable in two cases at Santiago. Otis mentions several cases of lodged

balls in the scrotum, the missiles having made their way thither from distant parts.

The treatment consists in strict antiseptic management because of the tendency to infection. The appearance of the latter calls for free incisions and thorough drainage.

CHAPTER X

Injuries to Blood-vessels and the Nature of their Lesions; Results of Injury to the Blood-vessels; Traumatic Aneurysms; Aneurysmal Varix and Varicose (Arterio-venous) Aneurysm; Injury to Peripheral Nerves.

Injury to blood-vessels as pointed out while referring to hemorrhage as a symptom of gunshot wounds has changed as to frequency, and also as to the nature of the lesion, with the change of armament. The vessels were wont to evade the pressure exerted by the low velocity round lead bullets of the old armament. As greater velocity was conferred on the projectiles, and as their shape became elongated, the tendency to escape injury on the part of the vessels was not so marked. The change that brought about the most characteristic results was coincident with the use of reduced-caliber bullets. The latter pass through the tissues so rapidly when animated by their greater velocity that the vessels have no time to be pushed aside. They either suffer (a) *contusion*, (b) *partial* or (c) *complete division*.

(a) Contusion of an artery includes any degree of injury which does not open the lumen. A contusion may consist of a slight traumatism involving laceration of tissues in the coats of the vessel with escape of blood from capillaries that infiltrate surrounding tissues, or the injury may be more severe, ending in necrosis of the coats of the vessel later. Bullets or larger missiles, moving at low velocity, when striking at a tangent, may cause laceration of the inner and middle coats of the vessel, without injury to the outer coat. Injury of a minor kind will heal without subsequent symptoms as a rule, or there may follow a thrombosis, at the point of impact, leading to obliteration of the lumen.

In severe contusion necrosis of the damaged part of the vessel may end in rupture, an occurrence which is common when sepsis has gained access to the injured part. In that event secondary hemorrhage will take place in ten to fifteen days from the receipt of the injury. Again, as a consequence of the lesion stated, a traumatic aneurysm may appear.

Among the ultimate or later effects of injury to neighboring tissues, a vessel may suffer contraction by pressure or traction from scar tissue. The volume of the pulse below the seat of injury may thereby be perceptibly diminished, or an audible murmur may be found at the point where the vessel is compressed.

(b) **Partial division** of an artery may occur from a displaced splinter of bone, a fragment of shell, a deformed bullet with sharp angles, or fragments thereof. The high-velocity small-bore bullet may cut away a notch in a vessel by striking it on the side, or in the case of vessels larger than its own caliber when it makes a regular impact in the middle of the vessel it inflicts two circular openings in the opposite walls of the vessel.

(c) **Complete division** of an artery is followed by loss of pulsation in the distal portion of the vessel if the collateral circulation is deficient. If anastomosis is free it will reappear later.

Wounds of veins are met with, and they are very similar to those of arteries.

The results of injury to vessels are thrombosis and obliteration, and the various forms of hemorrhage to which we have already referred. There now remain for consideration, traumatic aneurysms, and arteriovenous aneurysms.

Traumatic Aneurysms.—Aneurysms as a result of trauma from gunshot have a far-reaching importance to-day as compared to former times. As example, we may state that before the Spanish-American and Anglo-Boer Wars, traumatic aneurysms of the arterio-venous type were mostly seen in civil hospitals from stab wounds, injuries by machinery, and as a result of accident from the operation of venesection at the bend of the elbow in the days of blood letting. The experience of recent campaigns brings out the fact that surgeons now look to military instead of civil practice for the study of all forms of traumatic aneurysm, and that what was once a comparatively unknown trauma in military practice has become one of the distinct features of war wounds by the new armament.

Aneurysm as a result of trauma by gunshot occurred in seventy-four cases in the Civil War and forty-four cases in the Franco-German War, its appearance being one case for every 2000 wounded in the latter. While these figures represent the frequency of occurrence in former campaigns, a single observer in the Boer War like Graf found 4 per cent. of his wounded suffering from some form of traumatic aneurysm.

The frequency of blood-vessel injuries was apparent to us at Santiago where out of 1400 wounded we observed five cases of gangrene as a result of vessel injuries which required amputation, one injury to the subclavian artery, two cases of ligation of the brachial and two of the femoral for diffuse aneurysm, and one case of arterio-venous communication between the femoral artery and vein.

Follenfant relates that the Russian Surgeon Bornhaupt out of 3600 wounded at Karbine operated five times on vessels of the extremities for aneurysm, nine times for arterio-venous communications and that there were four cases of aneurysms cured following a period of rest.

Two varieties of traumatic aneurysm are recognized, viz., the diffuse and the circumscribed.

Diffuse traumatic aneurysm is due to persistent hemorrhage from an artery. The blood is effused into the surrounding tissues and the resulting lesion is more properly speaking a hematoma. This form of aneurysm, and the circumscribed variety also, are very common as a result of wounds from the reduced-caliber projectiles. They do not result so frequently from lead bullets, unless the latter have acquired a cutting edge from deformation. We stated under the subject of hemorrhage in the chapter on the Symptoms of Gunshot Wounds that free external hemorrhage was not of frequent occurrence with lesion of the larger vessels of the extremities and neck, because of the narrow track of the modern bullet. The narrow track is readily closed by a change of alignment of the apertures in the different layers of muscle, intermuscular septa and other soft parts. The occluded track arrests the external hemorrhage which would otherwise occur, and the result is free bleeding in the tissues which are dissected by the blood pressure causing considerable tension, interference to the venous circulation, and rise of temperature from absorption of fibrin ferment. Discoloration is present if the blood is near the surface. There may be fluctuation, loss of pulse and edema.

The hemorrhage generally continues from the time of injury, but the symptoms attending its presence are not manifest for some days. When a bullet has grazed an artery the remaining coats may not give way at once. In such a case the appearance of the aneurysm will not show itself under ten days to three weeks.

Treatment.—The indications for treatment of this form of traumatic aneurysm are similar to those for external primary hemorrhage. In the case of injury to smaller vessels or when the indications point to

cessation of hemorrhage, active interference should be withheld. Such cases generally go on to speedy recovery by keeping the parts at rest. If the bleeding persists as shown by increased tension, the tumor should be laid open, the clots turned out and the artery tied above and below the seat of injury. When this cannot be done proximal ligature to the bleeding vessels should be practised, but in all such cases the incision in the tumor should still be practised and the cavity cleansed of clots to relieve pressure, otherwise gangrene may supervene from interference with the circulation below. The value of the foregoing methods

Fig. 124.—Traumatic aneurysm radial artery from gun-shot wound by reduced caliber rifle bullet in the Russo-Japanese War. Treated by ligation and dissection of sac. discharged cured. Base Hospital, Heroshima, Dr. Tanaka, I. J. Army, Chief Surgeon.

Fig. 125.—Traumatic aneurysm of right brachial artery from gun-shot wound by reduced caliber bullet in Russo-Japanese War. Treated by ligation and dissection of sac. Discharged cured. Base Hospital, Heroshima, Dr. Tanaka, I. J. Army, Chief Surgeon.

of treatment was well exhibited in the Anglo-Boer War. "Of forty-five cases reported in detail, direct ligature was done in twenty-seven, with no death. . . . . In ten of these cases the vein had also to be tied. Proximal ligature was done in sixteen cases, with removal of the clot by a separate incision in two of the cases. None of these cases died, and in only one gangrene occured, after ligature of the femoral artery" (Spencer).

Direct incision and ligature of the vessel at the point of injury was practised very successfully also by the surgeons in the Manchurian campaign who generally deferred operation, whenever possible, until after healing of the external wound to avoid the complications which might arise from infection. The latter was a frequent attendant in vessel wounds by shrapnel balls, and but seldom noted in wounds by jacketed rifle projectiles.

Circumscribed traumatic aneurysms are the result of small openings made in vessels at the seat of a previous injury. The vessels are generally surrounded by dense tissues like the popliteal and the tumor is of

Fig. 126.—Traumatic aneurysm of brachial artery from reduced caliber rifle bullet, in the Russo-Japanese War, treated by ligation and dissection of sac. Discharged cured. Base Hospital Heroshima, Dr. Tanaka, I. J. Army, Chief Surgeon.

small size, seldom larger than a hen's egg and very firm. They are of a less serious nature than the diffuse variety of aneurysm just described. They have the expansile pulsation and bruit of spontaneous aneurysms.

The treatment is rest, under which the majority show a tendency to contract and they occasionally disappear. The tendency, however, is toward gradual enlargement, and to rupture finally. The operative treatment is usually practised sooner or later, and this consists in direct ligation above and below the seat of injury and dissection of the sac. If this method is impracticable, ligation just above the seat

of injury, Anel's operation, or Hunter's operation should be practised. Stevenson states that the majority of cases in the Boer War occurred in injuries to the popliteal artery and that the favorite operation was to place a ligature at the edge of the adductor magnus because it was less likely to cause gangrene than ligature of the femoral higher up. Here we have three (3) illustrations of traumatic aneurysms from the Manchurian campaign loaned by Dr. Louis Livingston Seaman. (Figs. 124, 125, 126.)

Arterio-venous Aneurysms.—Comminution between an artery and vein as a result of trauma is known under the designation of arterio-venous aneurysm. The communication is effected in two ways (1) aneurysmal varix—in which the communication is direct, the artery and vein being in contact; (2) varicose aneurysm—when a portion or complete sac exists between the two vessels through which blood flows from one to the other. These communications are more or less characteristic of gunshot wounds. They are seldom met with as a result of the traumata usually encountered in civil practice, except as the result of stab or punctured wounds. They were also noted in the days of the old-time operation of venesection at the bend of the elbow. In military practice they have become more frequent as a result of reduction in the caliber of the military rifie, and military surgeons report an increasing number of instances among the wounded in recent campaigns. The .30-caliber jacketed bullet may pass the line of an artery and vein lying adjacent to one another, notching both, or it may pass between the two vessels, notching their contiguous surfaces. The resulting injury later develops into an aneurysmal varix or a varicose aneurysm.

(1) Aneurysmal varix is less comomn than varicose aneurysm, but it is more frequently met with in those vessels which lie adjacent or closely opposed and firmly held together like the popliteal vessels or the femoral vessels in Hunter's canal. An aneurysmal varix is very apt to occur also as a result of pressure surgically applied to stay the flow of blood. In either case the amount of effused blood is limited, it is later absorbed, and the communication between the vessels remains with no intervening sac. An aneurysmal varix may also follow after the temporary presence of a sac, when the latter shows a tendency to diminish gradually, and finally to disappear with no semblance of a tumor remaining, so that the case which was originally an arterio-venous aneurysm is thereby converted into an aneurysmal varix.

Symptoms.—Three or four days after the receipt of the injury and

often longer, a thrill and murmur which are constantly present make their appearance. The thrill is more distinct, with slight palpitation; it extends over a considerable area and when the vein is exposed, during an operation, the pulsations of the artery convey visible vibrations to its walls. Auscultation reveals a murmur which is loud and said to be audible at a short distance. If the varix is in the neck, the murmur is distinctly annoying to the patient at night when he lies on the injured side. The tendency is toward dilatation of the artery immediately above the point of communication with the vein.

The prognosis in aneurysmal varix is generally favorable. There is a frequent tendency to rapid pulse from 100 to 140 per minute which can be lessened by a quiet mode of living. The dilated condition of the arteries above the communication with the vein which develops in the course of years was well shown in the case of Captain Theodore Mosher of the 22nd U. S. Infantry, who was shot by a Mauser bullet at Santiago, July 1, 1898. The bullet entered the left thigh in the middle of Scarpa's triangle and emerged at the level of and 1 inch posterior to the great trochanter of the corresponding side. External hemorrhage was severe at first and the patient lost consciousness. Wounds healed by primary intention in two weeks. When examined for the second time by Doctor Senn on or about July 15 ,the patient was anemic. There was a pulsating swelling in Scarpa's space directly under the wound, the characteristic thrill and machinery murmur extended some distance above and below the point of communication between the artery and vein. The officer convalesced very slowly. He was retired from active service and placed on duty with the District National Guard at Washington where he resided till the time of his death in 1911, thirteen years after the receipt of the injury.

Doctor Thomas N. McLaughlin his attending physician states that there was marked disturbance to his circulation in later years. The pulse at the wrist was fast at times, slow at others and nearly always irregular. The dilated arteries extended from the bifurcation of the common iliac to the lower third of the thigh. The disturbed circulation brought on portal congestion and enlargement of the liver from passive congestion, the liver margin extending as low as the umbilicus. The leg was edematous from pressure. There was pain, strong pulsation, and loss of sleep which brought on nervous strain. In 1906 the dilated condition of the arteries was very much increased, the pain and incapacity for physical exercise became more marked.

Cardiac hypertrophy, valvular lesion, albuminuria and anasarca were noted toward the last.

The treatment of aneurysmal varix will be included under that of varicose aneurysm as the measures of relief are quite similar for both conditions.

Varicose Aneurysm.—As stated already this is the more frequent of the two forms of arterio-venous communications. The formation of a sac between the two apertures in the injured vessels is favored by the anatomical relations of the vessels, and the amount of blood effused. The formation of a sac more often occurs between vessels that lie in a bed of loose areolar tissue as in Scarpa's triangle or the subclavian vessels. The separated condition of the vessels favors a greater amount of extravasation of blood. The latter becomes circumscribed, and forms a tumor which later becomes the sac of a varicose aneurysm. It is likely that more or less extravasation is present in all arterio-venous communications. The tendency is for the smaller amounts of effused blood to become absorbed before a sac is formed, while larger extravasations being only absorbed in part resolve themselves into the formation of a sac. Some of the operators in recent wars claim that in the majority of the lesions showing arterio-venous communications there is evidence of a well-formed sac or the remains of a pre-existing sac, showing that the natural outcome of the simultaneous wounding of the two vessels is toward the formation of varicose aneurysm in the early history of the majority of the cases.

Symptoms.—The pulsation, thrill and bruit noted as symptoms of aneurysmal varix are present in varicose aneurysm. In many cases the thrill is present only after the disappearance of the primary swelling which follows the injury. Makins states that in some cases of arterio-venous aneurysms observed in South Africa in the forearm, calf, and popliteal space the thrill was discovered by accident some weeks after the injury, after no serious vascular lesion had been suspected.

The murmur common to all these injuries is often referred to under the name of "machinery murmur," it is widely distributed, but the distinguishing feature between varicose aneurysm and aneurysmal varix is the presence of a tumor, showing expansile pulsation. The latter is often absent in the early hisotry on account of blocking of the artery, and also in large tumors before they have become circumscribed. In this stage the blood is diffused about the tissues, there is no definite cavity and the conditions are not favorable to the transmis-

sion of the wave as they become later with the presence of definite walls.

The prognosis is far less favorable than that of aneurysmal varix. The dangers which beset the patient are the same as those of spontaneous aneurysm. Once a tumor has formed the usual tendency is for it to enlarge just as it does in aneurysm from other causes.

Treatment.—For both aneurysmal varix and varicose aneurysm the first indication is rest in bed, which should be prolonged in accordance with the progress noted. In cases of varicose aneurysm rest in bed as stated may result in converting the case into one of aneurysmal varix, a condition far less serious. If the vessels implicated are in a limb, a splint of plaster of Paris, in addition to rest, will insure absolute quiet. As to the advisability for operative treatment this depends upon the vessels affected and the amount of disturbance present. The vessels of the upper extremity offer the best results for operative treatment, and this is especially true of the brachial and its accompanying vessels. The vessels of the forearm frequently show no serious symptoms so that operation there is not always necessary. The femoral and popliteal vessels should not be operated upon except in cases of necessity. In the leg the tibial vessels may be operated upon with safety.

The most effective operation for both forms of arterio-venous communications is ligation of the artery above and below and as near as possible to the point of communication without interference to the vein. This operation is nearly always practicable in the limbs and it is especially adapted to the relief of aneurysmal varix. Proximal ligature should be avoided when possible as it is apt to be attended with gangrene, although Stevenson states that in several operations where proximal ligature was tried in South Africa, gangrene did not appear.

Varicose aneurysms usually show a tendency to enlarge and eventually to rupture, in which case the indications are the same as for traumatic aneurysms of the diffused kind. Ligation above and below the point of communication in varicose aneurysms is the ideal operation in small tumors. The ligature should be applied in sound tissue as close as possible to the sac.

In arterio-venous communications involving the large vessels of the neck operation should be avoided until rendered necessary by the increasing effects of pressure from dilated vessels or extension of the sac, in the case of a varicose aneurysm. Here the most suitable and most generally the only operation available is ligature of the main trunk on the proximal side of the sac. The sac consolidates and disap-

pears in the course of a few months. The thrill and slight pulsations remain in some cases with no tendency to increase.

GUNSHOT INJURIES TO PERIPHERAL NERVE TRUNKS

Injuries to nerves by gunshot have assumed additional interest with the use of the improved armament in modern wars. Except in the case of injuries implicating the great nerve centers wounds of this class have been attended by a very small percentage of mortality. Gunshot injuries to nerves were formerly recognized as a group which often resulted in complete and permanent disability, accompanied by much suffering and only occasionally amenable to treatment. Doubtless much of the protracted suffering and hopeless condition arose from pressure symptoms as a result of lodged missiles, callus, and cicatricial bands in old infected wounds. Hopeless paralyses came from absence of our present knowledge of nerve suture.

The character of the wounds from the soft, larger-caliber lead bullets also added to the frequency of traumatism like severe contusion, and partial or complete division of nerve trunks. The same lesions also occur from the military rifle projectiles of the present day, the contusions are neither so extensive nor so frequent, but instead a large class of disabling wounds as a result of vibratory concussion on nerve trunks has figured prominently among nerve injuries in recent wars.

Concussion of individual nerves is almost entirely identified with the effects of the high-power rifle bullet and the degree of concussion noted is closely related to the velocity of the bullet at the time of impact. As pointed out in transverse lesions of the spinal cord from the same cause it is not necessary that the projectile should come in direct contact with the nerve substance. Temporary and complete loss of function of an adjoining nerve is common enough now, after fracture of the shaft of a long bone. The amount of concussion which the nerve trunk suffers, and the disabling effects thereform, are proportional to the resistance of the bone hit and the velocity of the bullet. Thus the effects are more frequently noted after a high-velocity bullet encounters the compact substance of the shaft than we find in cases where the bullet traverses the cancellous end of a bone. But concussion of a nerve from the vibratory impulse caused by the bullet traversing soft tissues alone is also met with, showing that the transmitted energy from the bullet alone is sufficient to produce the lesion that we call nerve concussion. Such a lesion may be accompanied by all the symptoms of complete section, which may persist for many months.

The nature of the anatomical lesion is not demonstrable microscopically nor macroscopically. All we know is that a section of the affected nerve is for the time being completely destroyed as a conductor of impulses, the connective tissue remaining intact. In discussing gunshot wounds of the neck we cited cases of nerve lesion from concussion observed at Santiago, to which the reader is referred.

We are specially indebted to Mr. Makins and Col. Sylvester[1] for the painstaking way in which they have described their rich experience in nerve lesions during the Anglo-Boer War. Cases which were once more or less obscure are now readily understood by the explanation of the transmission of vibratory concussion or the dispersion of the bullet's energy. Cases of this kind were duly appreciated by the older writers and especially by Acting Assistant Surgeons Mitchell, Morehouse and Keen, U. S. A., and quoted by Otis. In writing of such injuries to the brachial plexus, for instance, they attributed the paralysis to "brief compression of the (nerve) trunks during the movement of the missile or to agitation of the nerves through the tearing of tissues more or less remote." In other parts of their work they often use the word "commotion" to convey the meaning of vibration as a result of the bullet's energy. Such cases were not then so frequent as they are now because of the lower velocity and energy of the bullets then in use.

Symptoms of Concussion.—Among the most common symptoms will be found partial or complete loss of function which includes loss of sensation only or loss of both sensation and motion. The symptoms are temporary in character, lasting seldom more than a week or ten days. In slight cases there is complete or partial anesthesia of a transient character in the skin distribution of the nerve accompanied by tingling sensations. In the more severe cases the loss of motion and sensation is absolute as one always finds in the complete division of a nerve, with subsequent wasting of muscles and the usual trophic changes in the skin, nails, etc. Though seemingly hopeless, these cases, whether complete nerve degeneration has been established or not, undergo the process of regeneration, during which sensation is the first to return, to be followed by motion later on.

Contusion.—This traumatism is produced by slight contact of the bullet, secondary missiles or spiculæ of bone with the nerve proper, although the presence of any anatomical lesion is not always very

[1] Gunshot Injuries of Peripheral Nerves in Reports of Surgical cases in South African War by Lt.-Col. Sylvester, R.A.M.C. (Stevenson.)

definite. The symptoms of contusion are often attended with slight hemorrhage among the nerve fibers the presence of which is suggested by signs of irritation, like pain and hyperesthesia. Differentiation between concussion and contusion is often difficult. Generally, contusion is a much more serious condition than concussion.

Symptoms.—The symptoms of contusion, in so far as motion and sensation are concerned, resemble those of division of a nerve, but they are not so complete. There is still reaction of the muscles to the stimulus of electricity but it is diminished. Some of the muscles to which the affected nerve is distributed may exhibit complete paralysis, while others still respond to the faradic current. The loss of sensation is also irregular, occurring in patches. Trophic changes such as redness of the skin, eczema, club nails, pain, stiffness, polished skin, loss of hair, hyperesthesia and burning sensations may appear. The muscles may atrophy and become flaccid.

Recovery is always to be expected. This may be deferred for months, and then in cases of more or less complete paralysis recovery of wasted muscles will take place suddenly. Sensation, as noted in cases of concussion, usually precedes the appearance of motion, and its return is regarded as a valuable diagnostic and prognostic sign.

Partial Division.—This is one of the common traumatisms from gunshot. According to the reporters from the Manchurian campaign the large majority of such cases were noted as a result of injury from the jacketed bullets. Fischer states that Hashimoto found 77 per cent. and Schaefer 90.6 per cent. of their cases as a result of wounds by these projectiles. In most of the cases the larger nerves were slit by the bullets but bullets were also known to perforate nerves smaller than their own caliber. Slits were commonly seen in nerves of 3 mm. in diameter and over. Notching was more common than perforations.

Symptoms.—In partial lesions response to electrical stimulation is incomplete save in those cases attended with concussion, but the transient nature of the latter is soon revealed by return of sensation to electrical stimulation. The loss of sensation and motion is not prolonged in the distribution of those fibers which escaped division."

Complete Division.—This traumatism is commonly observed in the smaller nerves. It cannot well occur in the larger nerves like the great sciatic by the small jacketed bullet except as a result of injury from a deformed bullet and from shots when the bullet is travelling at a tangent to its line of flight. In such cases the largest nerves suffer complete section. The extent of nerve involvement depends upon the

angle of impact. When the bullet traverses the nerve at right angles the loss of nerve substance corresponds to the caliber of the projectile and when the course of the nerve is hit obliquely an inch or more of nerve tissue may be involved.

Symptoms.—Complete division of a nerve is followed by loss of sensation and motion in its distribution. In a few days the muscles fail to react to the faradic current and this is followed soon thereafter by the customary signs pertaining to reaction of degeneration and the well-known trophic changes in the skin, hair, nails, etc.

A positive diagnosis is to be made if there is total loss of response to electric stimulus by the nerve trunk, or the diagnosis is equally certain in the case of nerves superficially placed if the bulbous end can be identified by touch.

Treatment.—The treatment of injury to peripheral nerves is expectant and operative.

In the expectant treatment we employ warmth and complete rest by means of a splint for at least one month. At the end of this time if pain and tenderness have sufficiently passed away the use of the galvanic current, gentle massage and passive movement of joints should be commenced. Morphia is to be used to subdue pain only when absolutely necessary. Every precaution to prevent infection of the wound should be practised from the beginning as suppuration prolongs recovery and adds to complications like neuritis, and pain from subsequent contraction in cicatricial tissue.

The treatment by operation may be divided into (1) immediate, (2) intermediate and (3) operation for secondary involvement.

(1) **Immediate operation** is practised when for other reasons during an operation or exploration a divided nerve trunk comes into view in which case it should be sutured before the wound is finally closed.

(2) **Intermediate operation** should not be undertaken before the end of two months or more because the necessity for operation is often not revealed until this lapse of time. Operation is imperative at about this time when the nerve trunk has been completely divided, but the establishment of the presence of such an injury can only be made by the symptoms that develop, and these, as we have already pointed out, are so entirely simulated by the symptoms of concussion, contusion, or a combination of both, that it is always in order to wait a reasonable time for the signs of recovery that are sure to appear after these minor lesions. The recovery that follows the latter takes place without operation. The process of repair in concussion or con-

tusion is often prolonged since the nerve undergoes degeneration and subsequent regeneration of the distal end before signs of returning function are noted. Experience teaches that nothing is lost by delay in operating for division of a nerve trunk. Premature operations have often been undertaken only to find that the nerve trunk was intact and apparently normal such as we always expect to find in concussion with or without contusion.

In the case of a divided nerve operation should only be undertaken after the lapse of the time mentioned and after all reaction to faradization has disappeared, when the muscles continue to waste and the trophic changes mentioned are progressing.

When the opportunity arises to suture a nerve at the time of the primary dressing, this should be done under strict asepsis. Suturing is best done at this time with a small round sewing needle, threaded with fine chromicized catgut or silk suture, through the sheath of the nerve, employing the mattress stitch or Lembert suture. The ends of the nerve should be brought snug together to promote restoration of function. When the whole of the nerve trunk cannot be sewed together the parts or filaments that can be identified should be carefully sutured. When loss of substance has occurred stretching of the divided ends to secure approximation is permissible. When the loss has been considerable grafting the distal end to an adjoining nerve may be practised. The limb should be fixed with a plaster-of-Paris splint for several weeks in a position to avoid traction on the ends of the divided nerve. Later prolonged treatment by massage, electricity and gymnastics should be employed. The bulbous ends may be split and turned toward each other to fill the gap, or in place of this method the usual forms of splicing known to surgeons may be employed.

(3) **Operations for Secondary Involvement.**—Operation is often necessary when a nerve becomes painful and its function is otherwise interfered with by pressure in scar tissue or in callus. In such a case the nerve should be exposed, freed from all adhesions, and stretched. It sometimes becomes necessary to stretch nerves afflicted with neuralgia that were only grazed primarily by bullets, with no apparent lesion other than possible traction from adjoining cicatricial tissue.

CHAPTER XI

Gunshot Wounds of Joints

The gravity of wounds of the larger joints until recent years ranked next to those of the large body cavities. The present-day beneficent results in joint wounds by gunshot are far more striking to the military surgeon than they are to the civilian practitioner. The latter has noted marked improvement as a result of the introduction of antisepsis, while the former has in addition to antisepsis noted marked beneficence from the use of the reduced-caliber projectiles as well.

The happy results which arise from the use of the jacketed bullets were foretold by all the experimenters before the use of these bullets was undertaken in warfare. Those who were concerned in testing the reduced-caliber rifles in the beginning observed the striking change in the character of joint wounds especially. Since the destructive effects in tissues, as often stated already, are proportional to the velocity of the bullet, its sectional area, and the resistance which it encounters on impact, we found that the spongy nature of the epiphyseal ends of bones offer a minimum amount of resistance, and that the epiphyses except in the very proximal ranges, were perforated without fissure, in the same manner that soft tissues generally are perforated. In other words the tendency of the armored bullet, in passing through the joint ends of bones, is to make a clean-cut perforation without fracture and the chances of complete recovery, with the use of a simple dressing and subsequent immobilization, is assured in nearly all cases.

The lesion inflicted in the joint ends of bone by the large-caliber lead bullet in former wars favored the development of sepsis to a marked degree. The soft lead bullet was prone to lodge and it generally deformed on impact against the bony structures, thereby increasing its sectional area. The amount of laceration of the soft parts attendant upon the displacement of bone fragments caused extensive hematomata about the cellular tissue, the synovial membrane, and joint attachments. The bone itself was fragmented and fissured so that the lesion in itself particularly augmented the development and spread of the infection that was invariably carried with the ball,

as well as that which was forced into the wound with particles of clothing and the integument. Such cases were invariably septic, and the mortality was correspondingly great.

The changes that have been wrought in recent years from the use of antisepsis and the new armament are at once shown in the following tabular statements.[1]

PERCENTAGE MORTALITY FROM WOUNDS OF THE JOINTS IN FIVE WARS

Joint	American Civil War	Franco-Prussian	Japan-China (Haga)	Spanish-American	Anglo-Boer War
Hip	84.7	71.8	100.0	33.0	28.5
Knee	53.7	48.9	25.0	5.5	4.2
Ankle	26.9	24.0	0.0	0.0	0.0
Shoulder	31.1	35.5	0.0	0.0	3.7
Elbow	9.4	21.2	0.0	0.0	2.0
Wrist	12.9	12.6	0.0	0.0	0.0

CASES AND DEATHS IN EACH CLASS OF JOINT WOUNDS IN THREE RECENT WARS

Joint	Japan-China War (Haga)		Spanish-American War and Philippine Insurrection		Anglo-Boer War	
	Number	Deaths	Number	Deaths	Number	Deaths
Hip	1	1	3	1	7	2
Knee	16	4	77	2	95	4
Ankle	4	0	26	2	40	0
Shoulder	4	0	9	1	27	1
Elbow	16	0	44	1	49	1
Wrist	6	0	6	0	10	0
Total	47	5	165	6	228	8
Mortality, per cent.		10.6		3.6		3.4

[1] W. C. Borden, Lt.-Col. U. S. A., in Vol. II, Bryant and Buck American Practice of Surgery.

In the Manchurian campaign Follenfant, quoting from the Kharbine statistics of 1905, found 1382 gunshot injuries of joints with but seven deaths and seventy-two resections. It is safe to state that the latter were not from fractures caused by the reduced-caliber bullet but more likely shots from shell fragments or shrapnel. Projectiles from the latter sources still cause extensive fracture in the epiphyseal ends of bones, with tendency to suppuration. Surgical interference in the way of partial excision with drainage is to be practised in the large majority of such cases, in order to preserve life and limb.

Vibration Synovitis.—Mr. Makins has called the attention of the profession to synovitis as a result of the vibratory force which shocks a joint by the dispersion of the energy of the high-power modern rifle bullet. In such cases he found a "considerable amount of synovial effusion into joints of limbs in which the articulation itself was primarily untouched." He found these effusions also in cases where the soft parts alone had been traversed, in tissues near the knee-joint especially, and he attributes them to the shock of impact conveyed to the entire limb; but he found these effusions most generally after fracture of the diaphysis and notably so in the hip, knee- and ankle-joints, and not so often in the joints of the upper extremity. The theory of vibratory synovitis is most tenable to us and one that will no doubt attract the attention of military surgeons very much hereafter.

Gunshot wounds of joints are usually divided as follows:

1. Lesion of joint without injury to osseous structures.
2. Wounds of joint accompanied by lodged missile.
3. Lesion of joint marked by grooving of the articular ends of bones.
4. Perforation of articular ends across the joint.
5. Comminution of articular ends of bones.

(1) **Lesion of Joint without Injury to Osseous Structures.**—These were rare injuries with the use of the old armament. The capsule of the joint is opened by the bullet without inflicting injury to the bones entering into the formation of the joint. This is more apt to occur in the wounds of the knee. With the present-day military rifle bullet this occurrence is not infrequent. The ill effects are but slight, due principally to effusion of blood in the joint. There is little danger of infection. Rest on a splint is the only treatment required.

(2) **Wounds of Joints Accompanied by Lodged Missiles.**—This form of injury was present in olden times with the use of low velocities. The U. S. Army Medical Museum has a rich collection of such cases

from our Civil War. Because of the superior velocity conferred on the high-power military rifle of the present day, lodged rifle projectiles in joints are now of rare occurrence in war. Wounds of this kind are still common from shrapnel and fragments of shells, and from pistol balls in civil practice.

(3) **Superficial Grooving of the Bones.**—In these cases there is a superficial grooving, and although the joint is not so directly implicated, these wounds prove by far the most serious because of the great danger to infection which is inherent in the character of the wound. The

Fig. 127.

Fig. 128.

Fig. 127.—Photograph in case of Corpl. H. C. S., Co. "F," 122nd N. Y., shot March 27, 1865. Globular head of femur is shattered by conoidal ball which remains lodged. Head of bone excised at junction with neck. Acetabulum was involved. Died from peritonitis Apr. 8, 1865. No. 9821. A. M. M. collection.

Fig. 128.—Pvt. J. R. Co. "C" 69th N. Y. Wounded March 25, 1865. Died of exhaustion Apr. 6, 1865. Conoidal ball entered anteriorly and lies lodged in great trochanter. A fissure 6 inches long extends down the shaft from the point of lodgment. No. 98211, A. M. M. collection.

entrance and exit wounds in the skin are generally oval since the bullet enters and leaves the skin at a tangent to the surface. This in itself invites the development of infection. The injury to the capsule is often marked by a superficial tear of some length as seen in the knee especially, with spicules of bone protruding. The synovial sac is naturally more extensively involved from a long narrow track made

by the ball than it is when it suffers two direct perforating wounds. Movement of a joint so injured, a common occurrence in war, adds to the traumatism and to existing infection. Absolute fixation of a limb so injured should be practised at once. Wounds in the neighborhood of joints should all be treated as gutter wounds of the synovial membrane.

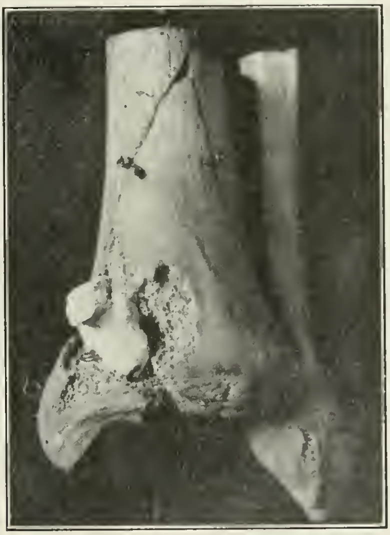


FIG. 129.—Pvt. M. J. 52nd N. Y. Photograph shows shattering of tibia into ankle-joint by conoidal bullet with long fissures extending in shaft. Shot at Chancellorsville, Mar 3, 1863. Amputation on fourth day after injury. No. 1173. A. M. M. collection.

4. **Perforation of Articular Ends Across the Joint.**—These are the most favorable of the joint perforations to treat and this is especially so with the shots delivered perpendicular to the joint surface, in which case the joint is traversed by the shortest route, inflicting a minimum amount of injury. (Figures 130 and 131.) Long oblique tracks through the bones are attended with more traumatism and greater liability to infection as in the case of the long narrow groves seen in shots which gutter the joint ends. The tendency to the development of infection in all joint wounds is measured by the size of the wounds of entrance and exit in the skin and the degree of traumatism in the structures entering into the formation of the joint. It is obvious from this statement that the amount of infection is largely dependent upon the sectional area of the bullet. Perforations of the articular ends of

bone by the armored bullets are generally clean cut without fissuring or splintering. In cases where the track of the bullet is near the surface of the bone, fissuring into the joint may occur, but these cases simulate those described under the Lesions of Joints Marked by Grooving, etc., and they are correspondingly serious.

Fig. 130.—Radiographs of left knee, showing lateral and postero-anterior view of left knee in the case of Pvt. Ernest Knowles, Co. "D," 21st U. S. Inf., wounded in Philippine Insurrection Oct. 28, 1899 by a ricochet .45 cal. brass-jacketed Remmington bullet. The ball entered external surface of thigh about its middle and passing perpendicularly through osseous structures of knee-joint, it lodged in the head of tibia from which it was removed by the author in May 1900. A shot obliquely or transversely disposed through the joint by such a large missile would have caused much destruction of bone with a less happy result. Remote effects: Some stiffness and pain in knee which disappeard partially after the bullet was removed. The photograph of bullet appears in Fig. 131. U. S. Soldiers Home X-ray Laboratory. Dr. A B. Herrick, X-rayist.

(5) **Comminution of the Articular Ends of Bones.**—Extensive traumatism of joint structures is usually caused by gunshot from shell fragments, large lead bullets, shrapnel balls and proximal shots at contact or only a few feet from the muzzle by the high-power military rifles of the present. (Fig. 132.) From the amount of fragmentation of the osseous structures, laceration of the soft parts and the larger skin wounds, these wounds are the most dangerous variety of joint injury, because of the presence and spread of infection which is almost inevitable in war wounds, especially in active campaign.

Symptoms of Wounds of Joints.—The first and almost invariable result of gunshot of a joint is the appearance of effusion composed of synovial fluid and blood which increases for the first twenty-four hours. In the less severe cases, under quiet and fixation of the limb, absorption will take place in from two to four weeks. A general rise of temperature will usually appear during this time from absorption of fibrin ferment in the effused blood or, as has recently been suggested, from the presence of staphylococcus albus. This rise in temperature is transient and slight and very unlike the fever and constitutional disturbance which accompanies acute septic arthritis.

Fig. 131.

Fig. 132.

Fig. 132.—Shows the result of an experimental shot in the cadaver of a man of 60 years by the U. S. A. pointed rifle bullet of .30 cal. impressed by its maximum velocity of 2700 f.s. Aside from the shattering effects of high velocity the brittle condition of the bones of the aged no doubt contributed to the degree of traumatism. Army Medical School X-ray Laboratory.

Escape of synovial fluid from the external wound occasionally occurs, and when it does it is positive evidence that the synovial sac has been penetrated, but cases of this kind are confined to large external wounds having free communication with the joint. When synovia is not seen, the diagnosis of joint injury is to be made from the track of the bullet as determined by the location of the external

20

wounds. When doubt of joint implication exists, the surgeon should nevertheless treat the case as one of joint injury.

Joints are sometimes implicated in injuries to the shafts of the long bones by the high-power rifles. Fissures of great length are frequently seen in the femur and humerus more often from shot injuries at the mid ranges. The fissures may or may not be subperiosteal and they extend into the neighboring joints causing more or less effusion into the synovial sac. These cases are difficult to separate from the vibration synovitis of Mr. Makins. In cases where the wound becomes septic, however, the presence of fissures into the joint becomes unmistakable because the septic process invariably extends along the fissures into the joint.

Treatment.—This includes (1) amputation, (2) excision and (3) conservative treatment.

(1) *Amputation* was the rule of treament in all wounds of large joints with the possible exception of the elbow in the days of the old armament. The lesion was then more extensive and sepsis was present in all cases. The surgeon's ability to control sepsis and the favorable character of the lesions inflicted by the modern military rifle has reduced amputation for joint wounds to a minimum in the wars of the present. Primary amputation is only done now in cases of great destruction of the soft parts and interference with the blood and nerve supply, such as are common from shell wounds. The surgeon is often tempted to save limbs when the vessels and nerves alone have been destroyed and when the injury to the joint proper is of secondary importance. Our experience among invalided and discharged soldiers at the U. S. Soldiers Home, Washington, has convinced us that conservatism can be carried too far and that when the blood and nerve supply have suffered extensive destruction amputation is better than conservation in the long run. The atrophied and paralyzed members have to be sacrificed ultimately. Primary amputation avoids a great deal of protracted suffering, and furthermore the soldier's pension, which is liberal for the loss of an arm or leg in our country, becomes at once available.

As far as known no amputation resulted either in the Spanish-American or Boer War for gunshot of a large joint by the small jacketed bullet. An amount of destructive effect necessary to require amputation from such a source could only arise at the proximal ranges when the bullet makes an irregular impact. Near shots are uncommon among war wounds now, they are more often the result of accident.

(2) **Primary Excision.**—For the same reasons that primary amputation has wellnigh disappeared from the field of military surgery, primary excision for gunshot of the larger joints is correspondingly rare. Except the removal of pieces of comminuted bone from wounds caused by shell fragments or shrapnel balls, nothing in the nature of an excision is done.

The knee and elbow may and do sometimes require secondary excision, at a remote period, to correct faulty positions or ankylosis, but beyond this, formal excisions for the ulterior effects of gunshot are seldom done in war hospitals.

(3) **Conservative Treatment.**—Before the days of antiseptic treatment and the use of the new armament the recognized mode of treatment of joint wounds was by primary amputation. Of the two factors that have brought about the present change in the treatment of joint wounds, it is difficult to state which of the two should receive the most credit. Joint wounds by the reduced-caliber bullets are generally so trivial, as far as the injury to cancellous tissue is concerned, that beyond a clean-cut perforation that heals in a few weeks under proper immobilization, the lesion has no characteristic feature worthy of mention. The external wounds generally heal under a scab and although a clean dressing is applied to the surface, it is doubtful if it plays much of a part in securing the primary healing that takes place in nearly all cases. At the same time that we would under no circumstances minimize the use of a clean dressing, we are very much of the opinion that the happy outcome of joint wounds under present conditions comes more from the humane nature of the lesion, and immobilization, than from anything else.

In joint injuries by the large-caliber bullets, and other missiles, which inflict more or less comminution, the antiseptic details necessary, no doubt, play a great rôle in saving limbs, and for these cases we would ascribe the greatest amount of credit to antiseptics.

The Spanish-American and Boer Wars, in a practical manner, plainly demonstrated the humane nature of joint wounds by the new military rifle, but we are happy to state that among the experimenters,[1] we were among those who foretold the outcome of joint wounds exactly as we find it to-day.

In cases of simple wounds of the synovial membrane and clean perforations of the epiphyseal ends of bones the conservative management of a joint wound comprises the use of a clean dressing applied

[1] Report Surgeon General, U. S. Army, 1893.

to as clean a field as one can obtain. Next the parts should be immobilized in a position to secure a useful limb should anchylosis occur. Passive movements and gentle massage should be practised as soon as the external wounds have entirely healed. Probing or any kind of exploration is not permissible.

In joint injuries exhibiting comminution of a moderate or severe kind, with lesion short of the destruction of soft parts, demanding primary amputation, experience has shown that the conservative method is still worth while. Such cases are only likely to arise from shell fragments, shrapnell balls, and proximal shots by the new military rifle. Except in cases in which the soft parts are badly damaged with interference of the blood and nerve supply, conservation, even though fragmentation is well pronounced, will yield useful limbs, if careful antiseptic treatment is persistently and rigidly carried out. These cases, unlike the more simple injuries to joints, require exploration, removal of loose fragments, irrigation, drainage, and immobilization.

In the emergent conditions of active campaign the military surgeon is often handicapped in carrying out all the painstaking details necessary to insure conservation. If he finds that he cannot maintain extension and counter-extension, and proper immobilization, because of enforced transport over any and all kinds of roads in unstable vehicles, he will then have to consider the question of primary amputation as a preferable alternative. Conditions of this kind are practically unknown to our civil confrères, but they are common enough with us, and for that reason military surgeons are often compelled to sacrifice limbs—lower limbs especially—that could be easily saved in fixed hospitals. An amputated limb will stand transport better than a comminuted joint, and the danger to life is far less by practising primary amputation.

If suppuration should take place in a joint while the surgeon is practising the conservative method, he should make free incisions in the dependent parts with liberal drainage and free irrigation of antiseptic solutions of suitable strength twice per day.

Gunshot Wounds in the Shoulder.—The wounds of this joint are necessarily often accompanied with wounds of adjacent parts like the clavicle, scapula, thorax, neck, face, forearm and hand. The projectile may enter the joint from the immediate front or from a lateral direction. Wounds of the shoulder are often received in this way but do not often implicate the joint proper and we may add further that gun-

shot wounds involving the joint have *diminished* in frequency with the introduction of the small-caliber military rifle. The reason for this is obvious. The largest calibers of the old armament were themselves almost as large as the globular head of the humerus, so that a hit in the vicinity of the joint was correspondingly more apt to open its capsule or cause lesion of its bony structure.

The statistics of former wars showed that gunshot of the shoulder-joint constitutes 2 per cent. of all wounds and 16 per cent. of all joint wounds. From our Civil War Otis reports 1400 cases of gunshot wounds of the shoulder-joint. In seventy-two of these there was no injury to bone. They were treated expectantly with a mortality of 8 per cent. In 1328 the articular extremity of the humerus or scapula was primarily involved. In 50 per cent. of the cases excision of the head of the humerus was practised; the expectant plan of treatment was followed in 37.50 per cent. and amputation was done in 12.50 per cent. The general mortality was nearly 33 per cent.

In 4919 gunshot wounds recorded in the Annual Report of the Surgeon General for 1900 occurring in the Spanish-American War and Philippine Insurrection there were nine gunshots of the shoulder-joint with one death, the immediate cause of which is not stated. Four of the cases were restored to duty, one was discharged at expiration of term, and the other three were discharged and pensioned. The wounds were the result of rifle bullets as follows: 4 Mauser, 3 Remington, 1 Krag-Jorgensen and 1 bullet not specified.

The amount of destruction that occurs in fracture of the bones entering into the formation of the shoulder-joint depends primarily on the sectional area of the bullet at the time of impact and next upon its remaining velocity.

The jacketed, present-day rifle bullet perforates or grooves the cancellous tissue of the anatomical neck, the lesion depending upon the angle of impact with the globular head. In either case there is little or no tendency to fissures. Formerly larger-caliber lead bullets caused great comminution of the globular head of the humerus. Even in shots which struck the anatomical neck at a tangent, there was not the tendency to gutter that there is with armored bullets.

A projectile striking the humerus at the junction of the anatomical and surgical necks will cause comminution of the globular head or separate it from the shaft. The separation will take place in the epiphyseal junction, thereby cutting off its blood supply, and incur

liability to necrosis. Delorme was among the first to point out this particular lesion.

When the projectile hits the surgical neck fissures will extend above to the globular head and below into the shaft and the comminution will be more extensive because the resistance of the compact bone in the surgical neck is greater. In such cases the upper fragment remains adherent to the periosteum and soft parts and furthermore it retains its blood supply, a condition which insures ultimate union of the fragments.

Some writers, Chenu among them, have reported the rare occurrence of dislocation of the head of the humerus as a complication of gunshot of the shoulder-joint.

Injury to the head and neck of the scapula are rare and when hit by armored bullets they are generally grooved or perforated. Lead balls and shrapnel may cause extensive comminution.

Treatment.—In cases of simple capsular wounds and perforations of the anatomical neck or head of the scapula the wounds and surrounding surface should be asepticized with antiseptic solutions or tincture of iodine. An antiseptic pad should be placed in the axilla and side of the chest. The arm, fore-arm and hand should be secured to the side and front of the chest by a wide roller bandage. No undue amount of examination to ascertain the extent of injury should be made. This can be later ascertained by X-ray examinations. Exploration by finger or instruments is not permissible.

When fracture by larger bullets or shell fragments occurs with comminution the management of the case has to be considered under the plans of (a) Conservative treatment, (b) Excision or (c) Amputation.

(a) **Conservative Treatment.**—This method should be practised in any kind of injury with comminution, short of destruction of the great vessels and nerves supplying the upper extremity. Later, if conservation fails, secondary excision or amputation can be performed with very little if any additional risk to life. If deemed advisable a thorough examination under a general anesthetic may be made to ascertain the amount of injury and for the removal of loose fragments. In this examination the wounds may be enlarged to facilitate the exploration and subsequent drainage. No fragment should be removed unless it is found to be entirely isolated.

Irrigation with boric-acid solution or a 1–4000 solution of bichloride

of mercury should next be made, drainage provided for, and after applying a clean dressing the limb should be immobilized.

From 50 to 60 per cent. of gunshots of the shoulder treated by the conservative method recover with partial or complete anchylosis and for this reason massage and passive motion should be practised early—as soon as the external wounds have healed. (Figure 133.)

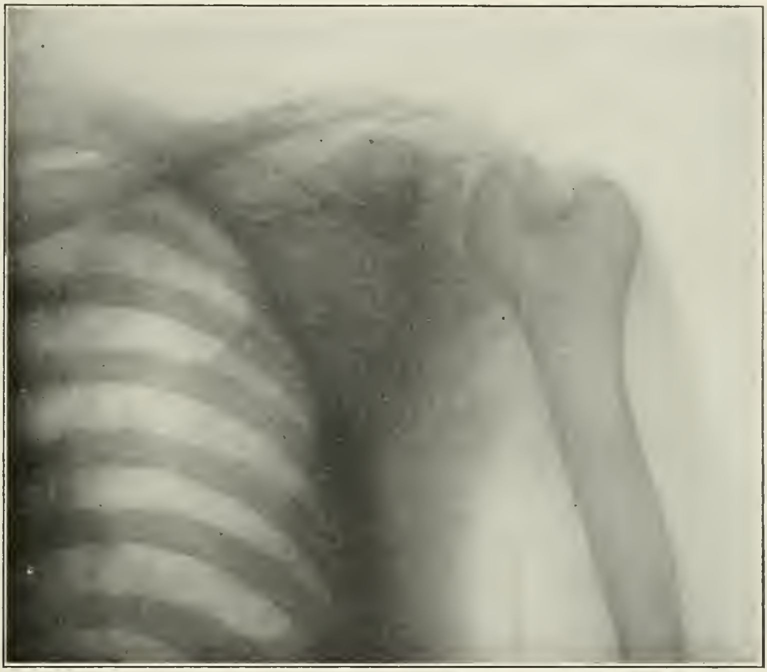


FIG. 133.—Skiagram showing the result of gun-shot by the .30 cal. Krag-Jorgensen bullet in a U. S. soldier who was shot at a distance of 5 feet, in Oct., 1901. He was treated in accordance with modern methods by removing all detached fragments, etc. There is excellent use of the arm. Exposure was made in 1911. Lettermann General Hospital Laboratory.

(b) **Excision.**—Before the days of antisepsis and the change in the armament primary excision was the favorite method of treatment in nearly all wounds of the shoulder-joint implicating its bony structures. Surgeons found by wide experience that their formal excisions, which were done with a view to removal of all fragments and most of the lacerated tissues, left a comparatively clean operative wound which was not so prone to the development and spread of infection as the original wound caused by the crashing effects of the projectiles of

that day. For this reason excisions were more popular than attempts at conservation. (Figure 134.)

Now that we ward off sepsis by antiseptic methods and that the character of the wounds has become less grave, formal primary excisions are not required. No operative interference is done except occasionally to remove loose fragments of bone, missiles and lodged pieces of clothing.

Fig. 134.—A recent radiogram showing excision in the case of Benj. R. Pratt, an ex-volunteer soldier who was shot in the shoulder in the Civil War in 1863. Character of missile unknown. Army Medical School collection.

When suppuration sets in with sepsis as a result of necrosis in and about the joint in cases where attempts at conservation have failed, *secondary excision* is in order. The excision should be thorough, and effective drainage with persistent irrigation should be employed. By adopting this plan of treatment the arm will be saved and amputation avoided.

Amputation.—As stated already primary amputation is indicated for severe comminution of the bones entering into the formation of the joint, with extensive laceration of the soft parts, and injury to the large vessels and nerves. *Secondary amputation* sometimes becomes necessary in attempts at conservation when osteomyelitis, gangrene or secondary hemorrhage appear as complications. Necrosis of a large portion of the humerus was a cause of amputation at the shoulder in preantiseptic days and the same may be said of long-continued suppuration in the joint. The greater number of the causes mentioned will seldom be met with when our modern methods of treatment have been followed.

Gunshot Wounds of the Elbow.—The wounds of this joint average from 1.5 to 2 per cent. of all wounds in war, and 35 per cent. of all joint wounds. The frequency of gunshot of the elbow ranks next to that of the knee.

The amount of lesion, as well known, is proportional to the sectional

area of the projectile on impact. With the use of the older military rifle as well as shots from shrapnel and pieces of shells there is much damage to osseous structures entering into the formation of the joint. Smaller projectiles, and especially the jacketed present-day bullets, inflict injuries that are more often circumscribed and restricted. Antero-posterior shots groove the prominence of the condyles of the humerus or perforate the epitrochlear notch with little fissuring. Contact shots—shots in which the impact of the bullet is conveyed to the articular end of the humerus without causing more than slight grazing—sometimes show separation of the epiphysis from the shaft, as in simple fracture. Shots disposed transversely through the epiphyseal junction badly comminute the lower fragment into the joint.

Injuries to the head of the radius consist of grooves and perforations, and when the ball strikes toward the shaft, away from the epiphyseal junction, a fracture with fissures occurs, such as one is apt to find in injuries to diaphyses generally.

Shots through the joint which involve the ulna rarely cause complete separation of the fragments. They partake more of the nature of grooves and perforations. Transverse shots at the base of the olecranon are apt to show long fissures into the shaft, while antero-posterior shots through the olecranon proper exhibit perforation with radiating fissures above and below, with fragments held together.

Taken as a whole gunshot lesions of the elbow-joint lend themselves specially to the conservative method of treatment.

Conservation.—This method of treatment, like all the operative measures had its share of mortality in preantiseptic times. Otis records a mortality of 10.3 per cent. in our Civil War. This was slightly lowered in the Franco-German War of 1870–71, viz., 9.8 per cent.

With the advent of antisepsis conservation has become the method of choice in all injuries of the elbow save the few which from the extreme amount of traumatism to bone and soft parts demand primary excision or primary amputation. Conservation is to be practised in all synovial wounds and all bone injuries like those to the articular ends of the humerus, ulna and radius already mentioned. As long as the nerve and blood supply are not entirely destroyed, no matter what the bone lesion may be, there is hope of a useful hand, which is after all the great desideratum, and conservation should be tried. Conservation is only contraindicated by traumatism of the joint com-

plicated by injury to the brachial artery; and yet in preantiseptic times some of the leading surgeons, notwithstanding the gravity of such extensive traumatism, essayed conservation, and sometimes succeeded. In these daring attempts they pinned their faith on the abundant opportunity for collateral circulation that is normally present about the elbow.

When we remember that the rules of conservation as they are now taught were established in preantiseptic times, we are all the more hopeful of its value under our present methods of wound treatment. One should, however, remember that conservation in the extreme traumatisms referred to—those implicating the blood supply—find no application in active campaign when transport is impending. Conservation with a precarious blood supply is apt to be attended by gangrene, an eventuality that requires watchful care, and an amount of attention that can seldom be bestowed, except in fixed hospitals. In such cases the military surgeon is often compelled to advise amputation when his civil confrère is able to save a limb.

Although the aim of the surgeon at conservation is directed toward a movable joint, the experience of war surgery affords but little encouragement for such an outcome. Otis records but three cases with good motion in our Civil War, the majority recovered with true bony anchylosis. Audet[1] found in 1135 cases of gunshot of the elbow from various sources but 2.5 per cent. with good motion. Following the Franco-German War of 1870–71 out of 163 cases Dominick found complete anchylosis in 82.8 per cent., partial anchylosis in 11 per cent. and good motion in 6.2 per cent.

We will expect better results in cases where suppuration is avoided hereafter. This will be especially so in those cases of injury to the synovial membrane alone, and the lesser bone injuries. The function of pronation and supination will be retained in cases where the head of the radius and its articulating surface escape injury notwithstanding the occurrence of anchylosis in other parts of the joint.

In the recent wars of which we have record nearly all cases were treated by conservation. Out of forty-four cases of gunshot of the elbow-joint in the Spanish-American War the mortality was 2.2 per cent. and in the Boer War out of forty-nine reported cases there was one death following amputation.

In conducting conservation of elbow cases the limb should be fixed in a position that will give the greatest use of the hand should

[1] Audet, Manuel de Chinergie d'armeé, Paris, 1886.

anchylosis result. To this end the forearm is flexed on the arm at a trifle less than a right angle and the hand should occupy a position half way between pronation and supination, the thumb pointing upward. The fixation apparatus should be so placed as to permit redressing of the wound without disturbing in any way the attempt at immobilization.

Exploration of the wound is only necessary in cases showing comminution of the articular ends of bones. In such cases the external wounds should be enlarged if necessary, or the joint may be exposed by a posterior and external incision running in the axis of the limb. All splinters and fragments of bone, pieces of clothing and missiles should be removed. The joint and wound should be irrigated thoroughly with a weak bichloride solution 1 to 4000. Drainage should be maintained for a few days.

The occurrence of infection should be met by thorough drainage and frequent irrigation, and if it persists secondary excision will have to be considered.

In less serious cases, where there is reason to suspect slight bony lesion, no exploration of any kind should be undertaken. Such cases require a clean dressing applied to a clean field, and fixation. In cases which progress to a successful termination without evidence of inflammation early passive motion should be practised. The time to commence passive motion will vary, but it should not be carried on to any extent before the healing of the external wounds.

Excision of the Elbow.—No primary excision of the elbow was done during either the Spanish-American or Boer War and such an operation will seldom be required in the war surgery of the future.

The operation is indicated in those cases that show comminution on exploration, with fragments entirely detached. If operation becomes imperative, the weight of opinion at present favors a radical rather than a modified excision. The mere removal of fragments is usually followed by anchylosis and the end results are not good. Provided the injuries to soft parts and nerves are not as extensive as to incur flail joint or useless hand, a complete excision is preferable.

Complete bony anchylosis of the elbow is very trying. It often leads to the necessity for excision at a remote period, the results of which are generally satisfactory. Complete primary excision is therefore the operation of choice whenever the lesion requires excision at all. In support of this view, the experience of the older surgeons

serves us in good stead. We know the value of primary excisions of the elbow, as far as the use of the arm and hand are concerned, by their statistics which are abundant. According to Gurlt the statistics of primary excision after the Franco-German War of 1870–71 were "good" in 29 per cent. of the cases, "moderate" in 53 per cent., and "bad" in 17 per cent. Otis reporting upon complete excision in our Civil War states that "a fair proportion retained a fair amount of control over the uses of the forearm and hand, a smaller number had very serviceable limbs, and in a few instances the usefulness of the limbs was hardly at all impaired." The Civil War surgeons were deterred from doing complete excision because of the mortality which attended operative procedures in that day. In the class of cases demanding excision, we should expect no mortality of any consequence in the future and the functions of the limb will no doubt be better preserved than they have been hitherto.

Complete primary excision is not to be recommended in gunshot of other joints, but for the reasons mentioned we believe that excisions of the elbow in the class of badly comminuted fractures mentioned will find favor in the wars of the future.

Secondary Excision.—This procedure will seldom be required when the wound treatment has been properly carried out. In pre-antiseptic times it was necessarily frequently done as a measure to save life when active inflammation had set in after attempts at conservation. Persistent chronic arthritis and necrosis were also among the later causes of secondary excision, and then excision was practised at a remote period. When the muscles remain in good functional condition excellent results are obtained from excisions at a remote period. Stevenson's experiences in such cases were exceptionally good after the Tirah Expedition and Boer War. He states that "all of the cases operated on were improved and in some of them flexion and extension were as complete as could be desired while the limb and new joint were strong and useful." If the case requires removal of the articular ends, the less bone taken away the better. The cases require persistent and continued attempts at passive motion, massage and electricity.

Primary amputation of the elbow is done as in other joint injuries when extensive injury to bone and soft parts is present with involvement of nerve trunks. Injuries to the brachial and its branches which threaten the occurrence of gangrene are debatable causes for amputation. The rich collateral circulation about the elbow often makes it worth

while to attempt the saving of a limb if the remaining lesions are of a character to warrant the effort.

Secondary Amputation.—The old-time common sequelæ and complications of gunshot wounds like osteomyelitis, necrosis and secondary hemorrhage, were rather frequent causes for amputation in gunshot of the elbow. The more common causes of secondary amputation now are for limbs that have become useless appendages as a result of the successful practice at antisepsis.

Gunshot Wounds of the Wrist and Carpus.—Gunshot of the wrist was not specially fatal in former wars. Otis makes out a mortality of 12.9 per cent. out of 1496 shot fractures of the bones of the wrist after all plans of treatment, like conservation, the various excisions, and amputations incident to severe lesions or complications like inflammation, sepsis, etc.

The lesions of the joint from gunshot will depend upon the size of the projectile. Frightful lacerations will occur from shell fragments, and shrapnel balls hitting the joint in a transverse or oblique direction. Lead balls from pistols or rifles shatter the lower end of the radius or ulna into the joint causing fissures to extend into the diaphysis. The first or second rows of carpal bones may be injured by dorso-palmar, oblique or transverse shots. Injury to the lower end of the radius and ulna implicating the joint is the most frequent lesion found, and the dorso-palmar direction is less harmful to the anatomical structures than the transverse or oblique perforations.

The effects of the modern bullet of small caliber are less likely to comminute the joint ends of the ulna and radius or the carpal bones. They groove and perforate the former and only shatter the carpal bones which they strike. They do not divide tendons nor lacerate tissues as the old lead bullets did, hence the danger of sepsis is naturally not so great. No deaths are reported from the Spanish-American or Boer War.

Conservative Treatment.—This method of dealing with gun-shot fractures of the wrist has been practised since the days of Paré and it is more applicable to-day than ever before. From our Civil War, and the Franco-German War of 1870-71, Otis and Screven report a mortality after the conservative plan of treatment of 7.6 per cent. and 11.4 per cent., respectively.

The results of conservation to the function of the hand and fingers are very much influenced by the presence of inflammation in the wound. In the preantiseptic era when infection of all wounds was the rule,

the patients recovered with anchylosis in the large majority of cases. But few soldiers recovered with function of the hand and fingers sufficiently preserved to enable them to return to the ranks. Out of 307 cases in the Franco-German War Screven found 264 or 82.4 per cent. who recovered with complete anchylosis, and hands more or less useless, and 56 or 14.6 per cent. with incomplete anchylosis and slight use of the hand. In the same war Gurlt out of sixteen wounded treated conservatively found but one retaining the function of the hand sufficiently to permit him to be restored to duty. In our Civil War out of fifty-eight gunshot of the wrist fifty-one recovered with anchylosis of the wrist, five with mobility marked by deformity, and three with flail joint. These disabilities were almost entirely the result of adhesions in the joints and tendon sheaths as a result of inflammatory exudate.

Under our present plan of wound treatment, which is directed toward the prevention of sepsis, in gunshot of the wrist of the less severe type, there should be no serious loss of function in the hand. The experience in the Spanish-American and Boer Wars fully justifies this statement, and the same will no doubt apply to the results in the Manchurian campaign when the official reports become accessible.

In the minor degrees of injury the wounds should be enlarged if necessary and loose fragments of bone removed. Irrigation of the wound and synovial sac should next be thoroughly done, drainage provided for, and the limb immobilized, in a clean dressing, with the elbow slightly flexed.

The appearance of suppuration in the joint at any time during the treatment should be met by free incisions on the sides of the wrist, to forestall abscess formations up the arm. When the joint has been cut into, additional exploration should be made for loose fragments of bone and if necessary a partial secondary excision may be made. Unfortunately the results, when extensive inflammation occurs and partial secondary excision is required, are not very encouraging as to the ultimate function of the wrist and fingers. Such cases only too often end in grip-hand which is not much better than no hand at all.

Primary Excision of the Wrist.—Complete and partial excision of the wrist for gunshot gave discouraging results in preantiseptic times. Otis relates six cases of complete primary excisions, one ending fatally after amputation. The other five recovered with impaired function of the hand, "but all things taken into consideration, in a better condition than if they had been subjected to amputation." If those

were the results, and the impression of the utility of the hand after complete excision in preantiseptic times, the outcome that must obtain henceforth should be more encouraging still. Complete primary excision is only required for wounds caused by shell fragments or lead balls which cause much disorganization of the bony articulation. Smaller projectiles and shots from reduced-caliber rifle bullets in any but proximal ranges will cause less fragmentation, and as this class of wrist wounds will form the larger number, partial primary excisions will be required in the great majority of cases.

In our Civil War partial primary excision and secondary excisions gave twice the mortality observed after the conservative plan of treatment. Sepsis played a great rôle in this outcome. The same may be said of the results concerning the utility of the hand. In the Franco-German War Gurlt found the end results in partial excision "good" in 6.25 per cent. of the cases, and "moderate," "bad" and "very bad" in 93.75 per cent.

Shots from the modern rifle bullet will not as a rule cause much impairment of the wrist-joint. The bone lesion will be marked by perforation or slight guttering of the articular ends of the ulna and radius, which will heal aseptically in the large majority of the cases. Mr. Makins "never saw any trouble result from perforations of the carpus" in the Anglo-Boer War. Secondary excision becomes necessary when sepsis as a complication makes its appearance in joints undergoing conservative treatment. The surgeon will have to decide whether partial or complete excision is to be employed.

In the after-treatment, fixation should be maintained in such a way as to permit passive motion of the thumb and fingers. Wadding should be placed between the thumb and index finger to prevent the former from becoming more or less anchylosed next to the latter. Passive motion of the digits should be commenced in a day or two and maintained along with massage and faradization all through convalescence and longer. The utility of the hand depends almost entirely on the attention thus bestowed.

Primary amputation is only required after extensive lesion to the soft parts and bony articulation from shell fragments, larger rifle projectiles, and wounds by fine and coarser pellets out of shot guns.

Gunshot Wounds of the Hip-joint.—The frequency of gunshot of the hip-joint as determined by Fischer was thirty cases for every 1000 wounds of all anatomical parts, and 5 per cent. of all joint wounds.

Of the injuries to the large joints those of the hip were the most

fatal. The diagnosis was always uncertain, and oftentimes obscure, and in active campaign they were among the most difficult to treat. Otis gives the results in 386 cases treated in the Civil War from the Union and Confederate armies. Of this number, in 40, the part of the joint involved is not stated. The acetabulum alone, or the acetabulum and some part of the head, neck, or shaft of the femur figured in the lesion in seventy-four cases. Sixty-four were treated by conservation and but two recovered, the fatality being 96 per cent. Nine were treated by excision, one by amputation, with a mortality of 100 per cent. The head of the femur alone, or the head and neck, the head, neck and trochanters, the head, neck and shaft, the upper portion of the femur or trochanter involving the joint were included in the lesion in 272 cases. Two hundred and three of these were treated by conservation with 160 deaths or a fatality of 58 per cent. as compared to 96 per cent. for the group which includes lesion of the acetabulum also. Out of forty-five excisions in the last group forty-three died, the mortality being 95 per cent. Of nineteen cases subjected to amputation, with a question as to the result in two, death occurred in every case.

By dividing the cases in the two groups—one where the acetabulum is implicated in the lesion, and the other where it is not, we find that treatment by excision and amputation was alike fatal in both, and that treatment by conservation of the cases with acetabular involvement gave an excessive mortality as compared to what we find in articular lesion without acetabular involvement, viz., a mortality of 96 per cent. as compared to 58 per cent.

Although sepsis might account for a large percentage of the fatalities in each group, it cannot account for the great divergence in the mortality of the two groups, for we must admit that sepsis arising from lesions without acetabular involvement should be as fatal as that arising with acetabular involvement. The larger death rate among the acetabular cases was no doubt connected with adjoining pelvic complications incident to the crashing effects of the large rifle projectiles of that period, and in this sense the death rate of this group cannot be taken as figuring entirely in the death rate of hip cases alone.

The comparatively low death rate of 58 per cent. in the second group, viz., in those cases showing lesion of the head, neck, alone or combined, or shaft, trochanter, and neck combined was not a bad result for that time and mode of treatment. If such cases had been

treated antiseptically, after our present methods without exploration with probes or fingers, except when urgently required, we have reason to believe that the results would have been exceptionally good, notwithstanding the comminution attending injuries by the old-time projectiles.

Because of the present-day tactics of firing in the prone position, the hip-joint is not so frequently wounded as formerly. When the soldier is lying down under cover the hip is one of the least exposed parts of the body. Mr. Makins saw but one case—a grazing of the edge of the acetabulum—in the Anglo-Boer War. Stevenson reports seven cases in the same war, and the Surgeon-General, U. S. Army,[1] reports three cases as having occurred in the Spanish-American War.

Pathology.—The effects of projectiles on the hip-joint include lesion of the (1) capsule, (2) trochanters, (3) the head of the femur, (4) the neck, and (5) the portion of the surgical neck adjacent to the intertrochanteric line.

(1) **Lesion in the Capsule.**—Projectiles passing antero-posteriorly or in the reverse direction can injure the capsule by grazing or actually perforating its cavity opposite the head and neck without implicating the bony structure. In the same way the capsule may be contused and even perforated by shots disposed tranversely from without inward or vice versa in front or behind the joint without implicating the osseous structure of the articulation proper. Otis refers to forty-nine cases of perforation of the capsule in the Civil War. Shots from the modern military rifle are especially apt to perforate the capsule without implicating the bony parts of the joint. Injury to the capsule by the modern rifle bullets with and without bone lesion is more often linear in shape, with apparently little or no loss of substance.

(2) **Lesions of the Trochanters.**—The greater and lesser trochanters may suffer contusion, grooving and complete perforation by projectiles traveling in any direction, with no special tendency to fissures from the point of impact. The lesion is limited for the projectiles of hand weapons, but especially so for jacketed reduced-caliber bullets in the mid ranges. The perforation by the latter on entering is clean-cut, while the lesion at the point of exit is larger and marked by the presence of small detached fragments, with others still attached. Fissures, if any, are more often subperiosteal and seldom extend beyond the limits of the apophyseal structure. Lesion from the

[1] Reports of the Surgeon General, U. S. A., 1899–1901.

larger-caliber lead projectiles like those of our .45-caliber Springfield rifle were attended with much comminution and fissures extending to the shaft and neck.

(3) **Lesions of the head of the femur** may consist of contusion, slight grazing, grooving, and perforations that are clean or attended with more or less fragmentation depending upon the sectional area of the bullet. When the force of impact is directed near the epiphyseal line with the neck, there is danger of separation of the head from the latter as was pointed out in similar shots in the shoulder-joint. The lesion is more apt to be circumscribed or to partake of the nature of a groove or perforation in shots from armored bullets, at medium ranges.

(4) **Lesion of the Neck of the Femur.**—Traumatism may here consist of contusion grazing, grooving or complete perforation with or without fissuring. A shot which grooves the circumference of the neck is attended with more or less fragmentation, the fragments remaining attached or set free in and about the joint depending upon the sectional area, velocity, and density of the projectile. When the force of impact causing either a groove or perforation is delivered at either end of the neck with fissuring, the latter will be disposed toward the epiphyseal line of the end hit, causing complete or partial separation of the neck, with the head or the trochanteric region, as the case may be. One of the larger rifle projectiles, like that of our .45-caliber Springfield rifle, striking the neck in any part of its circumference will at times, through the force of the energy delivered, cause fissures to occur simultaneously in the direction of the epiphyseal lines at both ends of the neck, thus partially or completely separating the latter. When the vibratory force is delivered at about the center of the neck traversing it through its thickest part the resulting traumatism will consist of a clean perforation with more or less fissuring and fragmentation—hits by the modern rifle bullets will be clean-cut like those which it exhibits through cancellous tissue generally, while lesion of larger-caliber leaden bullets will tend toward fissures and comminution which will correspond in extent with the sectional area and velocity of the bullet.

Diagnosis.—Before the introduction of the X-ray the diagnosis of gunshot of the hip was difficult and oftentimes impossible. The depth of the joint in the tissues made exploration with the finger through the wound very difficult. The physical signs of fracture such as shortening of the limb, eversion of the foot, disturbed relations of the bony points about the joint, or escape of synovia may be absent.

The joint is so well supported by muscles, ligaments and fascia that severe injury to the joint is possible when the patient still retains power of motion and ability to walk. Now that the armored bullets have come into general use this difficulty in diagnosis by the old-time physical signs is very much emphasized. The jacketed bullets groove or perforate the head, neck and trochanters of the femur almost invariably. Solution of continuity is seldom complete, and the physical signs of fracture will be absent as a rule. In such cases one will have to rely on the wounds of entry and exit, and take account of the tissues that have been traversed by the course of the straight line between the external wounds. Again in such cases hereafter the surgeon will have to invoke the assistance of X-ray evidence to set him aright. Formerly in cases of doubt the surgeon was advised to treat all suspicious cases as he would those of actual fracture, and the practice is the only safe one to follow now.

In the absence of the X-ray as an aid to diagnosis, or in cases in which the plate may show an obscure finding, there are signs which the surgeon should look for. Langenbeck laid stress on swelling of the capsule with blood which is most apparent on the front of the thigh just below Poupart's ligament. The pressure of the tumor back of the large vessels causes the femoral artery to pulsate perceptibly under the skin of the groin. Again in through-and-through shots the exact location of the "dangerous region" in hip cases as laid down by Lagenbeck must be carefully mapped out. According to him the "dangerous region" is included in "a triangle whose base intersects the trochanter major, while the femur and the anterior superior spine of the ilium form the points of an acute angle." Stevenson suggests a dangerous space included in "a triangle the angles of which are at the spine of the pubes, the anterior inferior spine of the ilium and the outermost point of the great trochanter. The value of any space, defined by invariable lines, is necessarily faulty. This was true in the days of the old armament, and it becomes more so with the use of present-day rifle bullets. The joint capsule may be penetrated by reduced-caliber bullets antero-posteriorly or vice versa time and again without implicating the osseous structures by passing above or below the neck of the femur.

Treatment of Gunshot of the Hip.—The management of wounds of the hip will be considered under the following heads: (1) Expectancy, (2) Conservation, (3) Excision, (4) Amputation.

Expectant Treatment.—This plan contemplates no exploratory or

operative interference. Immobilization and a clean dressing to a clean field are the only requirements of treatment. This plan is applicable in doubtful injuries to the joint, in which the external wounds and the course of the intervening track are the only evidence which tends to lend a suspicion of joint lesion. In such cases, with the use of the present armament, there may be wound of the capsule only, or slight injury to bone, such as grooving or a clean-cut perforation. In such cases immobilization and a clean dressing have given uniformly good results in the Spanish-American and Boer Wars.

Conservative Treatment.—This plan of treatment is to be pursued after a positive diagnosis of gunshot fracture of the hip-joint has been made. The surgical means to be employed are: (1) exploration of the joint; removal of bone fragments or missiles; (3) immobilization.

In cases requiring the measures which aim at conservation there will usually be the signs of fracture such as shortening of the limb, eversion of the foot, disturbed relations of the bony points about the joint, escape of synovia or lodged ball. In addition there will be evidence of the character of the lesion from the knowledge of the caliber of the projectile which inflicted the injury as judged by the external wounds, and also from the velocity of the projectile or distance at which the injury was received. Injuries to the bones of the hip-joint by shell fragments when not too large; lead bullets of the larger calibers from rifles, revolvers and shrapnel; as well as steel-clad bullets from pistols and military rifles at proximal ranges usually cause fragmentation that requires surgical interference.

Exploration, when two wounds are present, can usually be practised through the wound of exit. This should be enlarged to admit the finger when necessary. Missiles or small loose fragments of bone that can be readily removed should be extracted with the aid of the finger and forceps. Larger fragments that lie absolutely loose, free from bony, periosteal or soft parts, will necessitate enlargement of the wound and for this purpose the posterior incision employed for excisions should be done. The joint and wound should next be irrigated and drainage at a dependent point should be provided for.

Immobilization is the next and last of the measures in the scheme of conservation. Fixation of a limb is easy enough in a stationary hospital, but in active campaign where the military surgeon encounters the majority of his cases it becomes a vexatious problem—one that will often tax the ingenuity of the surgeon to the utmost. During enforced transport immobilization is next to impossible.

The method of fixation must include the whole limb and pelvis, and the wounds should remain uncovered by the fixation apparatus, with ready access for redressing.

Plaster of Paris is the most desirable method of fixation as it insures immobilization and, when properly applied, extension and counter-extension at the same time. Nothing can take its place in any and all kinds of transports. Unfortunately, it is not always adapted to the emergent conditions of field service on account of the time which is required to apply a suitable splint. Surgeons should be thoroughly familiar with the method of applying plaster of Paris for use in hip cases, because, unless the splint is properly fitted, it does more harm than good.

Fixation of whatever kind should be practised at once, from the time a man is wounded on the field. In the absence of any better method, Delorme and other surgeons advise bandaging the injured limb to the sound one after placing sufficient padding between the two members in order to avoid discomfort and to secure proper position.

Wire gauze splinting, extension and counter-extension when practicable, or any of the methods used in field practice or stationary hospitals to immobilize limbs may be employed provided immobilization is complete and well maintained.

The presence of suppuration in and about the hip-joint should be treated by free drainage and frequent irrigation with antiseptic solutions like mercury bichloride 1–4000. Such cases usually get well with more or less anchylosis, but when the suppuration continues excision will be in order at a later period, when the active inflammatory process has subsided. Ample nourishment and administration of stimulants should be given in the meantime, to build up the strength of the patient, and to prepare him for such subsequent measures of surgical relief as may be deemed necessary.

As we have already stated in the beginning of this chapter the results in future wars will be very encouraging for all the plans of treatment and especially for those after conservative treatment.

Excision of the Hip.—Hitherto the results of this operative measure have been alike deplorable in civil practice and active campaign. We cite below the mortality recorded by Otis for the different periods in the clinical history of such cases before the days of antisepsis.

NUMERICAL STATEMENT OF SIXTY-SIX CASES OF EXCISION AT THE HIP-JOINT FOR SHOT INJURY DURING OUR CIVIL WAR

Operations	Cases			Per cent. of mortality
	Recovery	Fatal	Total	
Primary operations	1	32	33	96.9
Intermediary operations	2	20	22	90.9
Secondary operations	3	8	11	72.7
Aggregates	6	60	66	90.9

Otis again collected the statistics of 161 cases of excision and the mortality among these was as follows:

Primary operation	93 per cent.
Intermediate operation	96.6 per cent.
Secondary operation	63.4 per cent.

The statistics of Gurlt and Langenbeck collected in the German wars of about the same period give results only a trifle better.

Notwithstanding the high mortality observed by Otis, this author boldly advocated primary excision in all uncomplicated cases of shot fracture of the head or neck of the femur. He wrote at a time when expectant and conservative methods of treatment were invariably followed by sepsis and death, or complications that ended in prolonged suffering. Under our present methods of treatment we no longer advocate primary excision for uncomplicated fracture of the head or neck of the femur. It has been almost entirely supplanted by conservative methods. Out of three cases in the Spanish-American War,[1] and eight in the Anglo-Boer war (Stevenson) so treated, there were three deaths—a mortality of 27.2 per cent. Although this number is small to predict the outcome in other wars we confidently believe that it will serve as an index of the official reports of the Manchurian and Turko-Balkan campaigns, when these are published.

Intermediate Excision.—The mortality is rated so high when the operation is performed at this stage in the clinical history of such cases that it should be seldom resorted to. It may be contemplated

[1] Report S. G. O., U. S. A., 1899–1901.

in cases which might have suffered excision primarily, when the latter was delayed for insufficient diagnosis, or proper opportunity to control one's surroundings; but in such cases it will always be wiser to adopt conservative measures such as the removal of loose fragments of bone, free irrigation, drainage, and the careful use of antiseptic materials. In this way one will often succeed in arresting an active inflammatory process or in tiding the case over to a suitable time for a secondary excision.

Secondary excision is practised when efforts at conservation fail through the introduction of sepsis into the wound, and when all efforts to stay the inflammatory process have been unavailing. In such cases necrosis of bone is common, fragments primarily attached have become loose, and the case requires thorough exploration and excision to remove all diseased tissues properly.

There were but eleven secondary excisions recorded in our Civil War by Otis, with a mortality rate of 72.7 per cent. The number of cases for this great war is small, but it is accounted for by the fact that comparatively few patients survived injuries involving the hip-joint until the time for secondary excision had arrived.

Otis observes (1883) that since the Civil War the operation of excision of the hip for shot injury has been practised five times in the U. S. Army and once in the U. S. Navy and this aggregate of six cases gives four recoveries. We took one of these army cases off the field during an Indian campaign in Wyoming in 1876 along with a number of others seriously wounded. The following is an abstract from the history[1] of the case: Sergeant William J. Linn, Co. M, 4th Calvary, was shot Nov. 26, 1876, with a 50-caliber conoidal bullet weighing 412 grains in a battle with Indians. The ball passed through the right hip-joint while he was resting on his right knee and left foot in the act of firing his carbine. A plaster-of-Paris bandage was applied to the injured limb at once, including a spica around the waist, and the next day he was moved on a *travois* through a mountain region without roads, in excessively cold weather. We reached our base of supplies on the third day. The plaster-of-Paris cast was here removed, and after establishing free posterior drainage a new plaster-of-Paris cast was securely applied as before and the patient was carried by ambulance five days over a country devoid of roads, in what was then known as the most inhospitable region of our country, in cold weather that hovered around zero most of the time. Lieutenant John Van R.

[1] Med. and Surg. History War Rebellion, Surg. Vol., Part III, p. 123.

Hoff, Medical Corps, now Colonel U. S. Army, retired, who reported the case successfully performed secondary excision of the hip-joint ten months later. He found the head of the femur loose in the joint cavity. It had been severed from the neck by the bullet and this with other necrosed bone including the upper end of femur just below the great trochanter, were entirely removed. Two years later this soldier had so far recovered the use of his limb that he got along without a crutch, and only used a walking cane on long walks.

We believe this case was tided over the active inflammatory period during transport because of good drainage and thorough immobilization with plaster of Paris. Our attempts at antisepsis in that time were very crude, and under the conditions then prevailing sepsis was unavoidable.

The best method of performing excision of the hip need not occupy us here. Generally speaking the posterior incision extending from a half-inch below the anterior superior spine of the ilium and passing downward over the most prominent part of the great trochanter will afford better drainage and in cases in which the greater trochanter is implicated the opportunity to observe the extent of lesion and remove loose fragments makes this incision particularly advantageous.

The after-treatment is the same as that for chronic hip-joint cases generally.

Amputation of the Hip-joint.—The results of all amputations at the hip-joint in military practice were collected by Otis, including the sixty-six cases which occurred in our Civil War. The mortality is thus referred to by the great author—"we thus arrive at an aggregate of 250 cases of exarticulation at the hip as the present status of this grave mutilation in military surgery, with twenty-seven recoveries, 222 deaths, and one example with unknown result or a mortality of 89.1 per cent." Of twenty-five primary amputations among the sixty-six cases in the Civil War death occurred in twenty-two cases, a mortality of 88 per cent. The operation in the intermediate stage in twenty-three cases gave the usually high mortality—100 per cent., and 77.7 per cent. in nine cases in the secondary stage. In thirteen of the twenty-two fatal cases in the first group the wounds were inflicted by cannon shot, shell fragments or other large projectiles causing in all instances extensive mutilation, and noted in words like the following: shattering of the femur high up and mangling of soft parts, tearing away of muscles and comminuting the neck and trochanters, inflicting terrible laceration of the upper and exterior part of

the thigh, comminuting the upper third of the femur and fracturing the tuberosity of the ischium, etc., etc. In six instances it was necessary to perform primary disarticulation at the hip because of graver injuries to the femur conjoined with lesions of the femoral artery. Of the three who recovered the first was struck by a fragment of a 24-pounder shell crushing the trochanters and neck of femur and wounding the femoral artery, the second received a conoidal ball fracture of the right femur, fissures extending into neck quite within capsular ligament, and the third suffered comminution from a round ball and buck, comminuting the femur just below trochanters.

It is interesting to note that of nine reamputations at the hip-joint for osteomyelitis and other secondary complications there were but three deaths—a mortality of 33.3 per cent. The reamputations were rendered necessary in cases which had suffered amputation in the middle and lower third of the thigh.

In three secondary disarticulations in the Spanish-American War there was one death and in the Anglo-Boer War Stevenson reports thirteen cases with eight deaths, making an aggregate mortality of 56.2 per cent. for the sixteen cases in these two wars.

Shock and hemorrhage cause the great mortality in primary amputation of the hip-joint. The environments in active campaign rather forbid the risk attendant upon such a marked capital operation. The rule of the present is to postpone all cases, when possible, to the secondary stage and at a time when the environments are more propitious.

In those cases of injury by shell fragments which are apt to destroy the limb, Langenbeck recommended removal of the head of the former primarily, leaving amputation of the limb to be practised later. In this way the extreme additional shock of amputation is avoided. With the resources of modern surgery at hand, except in very extensive injuries of the soft parts, the management of the cases should be directed toward saving the limb, and should this prove unavailing secondary amputation can be practised later with far less danger to life.

Wounds of the hip-joint in recent wars are necessarily few in number. We await the official reports from the Manchurian and Turko-Balkan campaigns with confident hope of renewed achievements for modern surgical practice.

Gunshot Wounds of the Knee-joint.—With the use of the old armament wounds of the knee-joint numbered 28.7 per cent. of all joint wounds in military practice and 3 per cent. of all war wounds.

The frequency of gunshot of this joint is now less than formerly because of modern tactics which require men to fight under cover. Out of 4756 gunshot wounds of all parts tabulated by the Surgeon-General[1] in the Spanish-American War, injuries to the knee-joint constituted about 23 per cent. of all joint wounds, and 1/2 per cent. of wounds of all parts.

For purposes of study gunshot wounds of the knee-joint are divided into: (a) simple perforation of the synovial sac without accompanying lesion of any bone; (b) injury to the joint with lodged ball; (c) injury to the joint exhibiting guttering of the articular ends of the bones; (d) complete perforation of the articuler ends of bones in different directions; (e) implication of the joint by fissuring and comminution of the bones entering into its formation.

(a) **Simple perforation of the synovial sac** is known to be of more frequent occurrence now than formerly. During the days of larger calibers it was necessarily infrequent, but so late as the Civil War, under the designation of peri-articular wounds, Otis collected 351 cases with a mortality of 29.9 per cent. Of the 351 cases, he estimates that 255 cases suffered direct involvement of the capsule without fracture "and that in ninety-six cases the projectiles did not injure the joint, which was opened by secondary traumatic arthritis." Considering the difficulties of diagnosis which prevailed at that time and the fact that many of those who got well were not actually verified as simple synovial perforations, it may be admitted with propriety that some of Otis' cases were complicated by at least slight osseous lesions. Nevertheless it has been definitely ascertained by actual experience and by experiment that a bullet can traverse the joint, when the leg is in any position except complete extension by entering below the patella and ranging antero-posteriorly. It thus finds sufficient room to pass through the intercondyloid notch without inflicting fracture of the articular ends. There is sufficient space from side to side under the extensor muscles for a ball of moderate diameter to penetrate the reflection of the synovial membrane in that region. Again, when the knee is slightly flexed, the tibia and condyles are widely separated and there is ample space for a bullet to traverse the synovial sac in the anterior third of the joint behind the patella. Examples such as those mentioned were noted with the larger calibers by military surgeons in all wars and they will be far more frequent with the use of reduced calibers henceforth. Peri-articular wounds with involvement

[1] Reports of S. G., U. S. Army, for 1898–99.

of the synovial membrane will be as frequent as formerly. Stevenson states that wounds of the synovial membrane alone were fairly common in the Boer War.

(b) **Injury to the Joint with Lodged Ball.**—Projectiles have been known to lodge in the joint cavity without implicating bony structures. Balls lodge in or about the knee-joint more often than in any of the

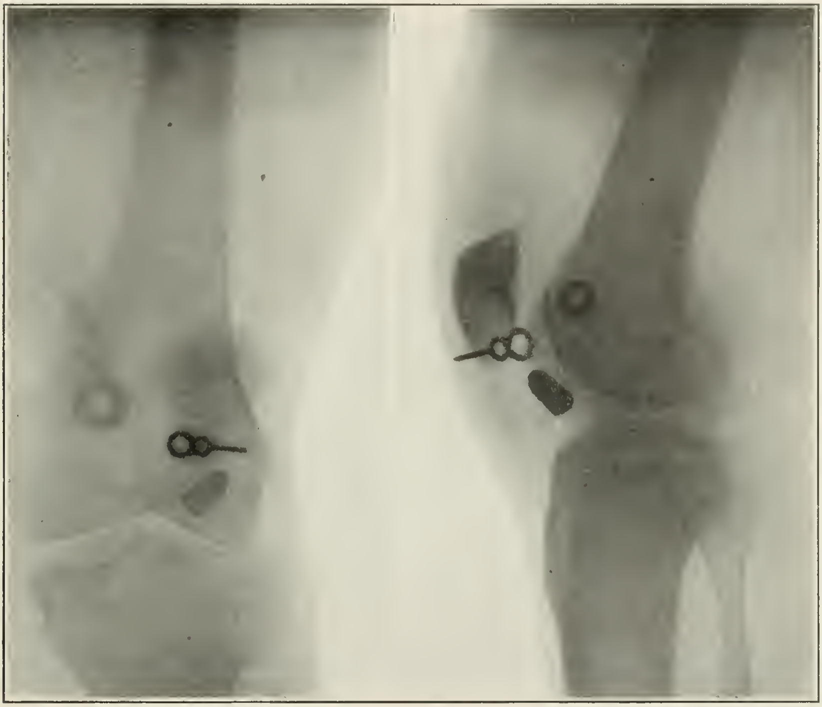


FIG. 135.—Radiogram showing postero-anterior and lateral views of knee in case of Pvt. William R. Barret, 29th Co., U. S. Coast Artillery. Exposure was made in 1909. This man was shot prior to enlistment with a .38 cal. Smith and Wesson revolver and the presence of the missile in the knee was not detected until he had been in the service some time. The washers were used as localizers. Army Medical School collection.

articulations. They are at times found in the joint but more often they are located in the epiphyseal ends of the tibia or femur. (Fig. 135.) Lodged balls in or about the knee formerly proved a serious complication in gunshot of this articulation (Fig. 136). Much harm was done in attempts to explore for the missile, and the search was more often futile. Under our present methods of diagnosis with

the aid of the X-ray, knee cases complicated by lodged balls are promptly relieved. Out of ninety-five gunshot of the knee in the Anglo-Boer War lodged bullets were removed from ten cases (Spencer).

(c) **Injury to the joint exhibiting guttering of bone** is one of the frequent lesions about the articular ends of the femur and tibia with the use of reduced calibers. The lesion may be superficially disposed about the contour of the joint ends, or there may be a superficial

Fig. 136.—Pvt. Roman Carinom, Co. 18th Philippine Scouts, wounded by what was thought to be a reduced caliber rifle bullet in engagement with Moros in 1912. Missile which appeared to be part of the core of an armored bullet was removed by opening joint. It was imbedded in articulating surface of outer condyle. Army Med. School collection. X-ray Laboratory, Division Hospital, Manila, P. I.

grooving of the joint surfaces proper, with spicules of bone protruding. The amount of lesion in any wound exhibiting grooving will necessarily be proportional to the sectional area of the bullet. Grooving by the modern bullet is clean-cut except in shots delivered at the proximal ranges. Here there may be short fissures radiating from the track of the bullet with detached particles of bone in the joint or in adjacent tissues.

(d) **Complete perforation traversing the joint in different directions** were occasionally noted in the days of the older calibers, but they

have become especially common since the adoption of steel-jacketed rifle bullets, and they are typically shown in the bony structures of the knee. In the mid ranges clean-cut perforations are the rule through the patella, condyles of the femur and the epiphyseal end of the tibia. Proximal shots from the new military rifle which perforate near the joint surfaces may exhibit fissures opening on the joint surfaces, but when present they are more apt to be subperiosteal in nature. As already stated perpendicular shots, which cross the joint by the shortest route inflict a minimum amount of injury and are attended with the best results.

(e) **Implication of the joint by fissuring and comminution of the bones** entering into its formation was the common lesion inflicted by shell fragments and the old lead rifle bullets of former times. In modern wars they are still observed as a result of shell fragments and shrapnel balls. The amount of lesion is always proportional to the sectional area and velocity of the projectile on impact. A shot from the larger calibers at proximal ranges which strikes the lower end of the femur just above the intercondyloid notch is apt to detach the condyles from the shaft as a result of deep fissures extending upward. The diaphysis of the tibia just before it unites with the upper epiphysis is made up of hard compact bone, so that shots at high velocity and sufficient sectional area near the epiphyseal junction will at times comminute the epiphysis into the joint, producing isolated fragments of varying sizes. The tendency, however, with armored bullets of reduced calibers is to make perforations in the epiphyseal ends of bones, and this tendency is still observed in the diaphysis adjacent to the knee-joint whether the bullet traverses the upper end of the tibia or lower end of the femur.

Diagnosis.—The diagnosis of wound of the joint will rest largely upon a study of the location of the apertures of entrance and exit. Effusion of blood into the joint, swelling, pain and inability to move the knee, are all valuable signs. Fracture will be attended by crepitation. Displacement of bony fragments when present is an absolute sign. The amount and kind of lesion and the presence of lodged missiles will have to rest on X-ray evidence.

Treatment.—The treatment employed in preantiseptic times was (1) amputation, (2) conservation, and (3) excision. Among these methods amputation was the rule adopted in our great Civil War, and the surgeon who adopted any other course in any gunshot wound of the knee was considered to be remiss in his duty to his patient. Conserva-

tion and excision were only practised in those cases where the patient refused amputation. The limb was sacrificed even in those cases where the joint capsule alone was supposed to be injured. In 313 cases of this kind treated without operation the mortality was 22 per cent. (Otis).

When antisepsis was first adopted our earliest observations of its value in military field practice were brought forth by Reyher and Von Bergmann in the Russo-Turkish War of 1877–78. Reyher reported eighteen primary aseptic cases of wounds of the knee, regardless of the extent of joint involvement, dressed antiseptically, of whom three died, a mortality of 16.6 per cent. The treatment was entirely conservative. He employed weak carbolic-acid irrigations in severe cases while the simple cases were cleansed and dressed with wet carbolic gauze. Those who got well recovered with movable joints.

Von Bergmann used the same antiseptic details in fifteen cases of gunshot fracture of the knee with fourteen recoveries, two of the successful cases having suffered amputation. The only fatal case was one in which amputation was practised. Although no reference is made as to the utility of the limbs in the non-amputated cases, it is presumed that they got well with movable joints. Since the experience of Reyher and Von Bergmann was obtained prior to the introduction of the new military rifle, their cases must represent injuries by the old leaden conoidal bullet of about forty-five calibers, weighing approximately 480 grains, and having an initial velocity of about 1300 f.s.

Gouped together we find that the cases of Reyher and Von Bergmann which suffered lesion from similar weapons and which were treated antiseptically have an aggregate mortality of 11.1 per cent.

The statistics recorded by Otis show that in 868 gunshot fractures of the knee in the Civil War treated by conservation there was a mortality of 60.6 per cent. Amputation as a mode of treatment was practised in 2431 cases. When amputation was performed through the joint the mortality was 56.6 per cent. and when it was done through the lower third of the femur the mortality was 53.6 per cent.

Compared to the results obtained in the Civil War in preantiseptic times after lesions of the old armament, the results of Reyher and Von Bergmann with practically the same kind of wounds, aided by the use of antiseptics, stand out as a great triumph in favor of modern methods.

The cases treated in the Spanish-American War and Philippine

Insurrection from 1898 to 1902 numbered seventy-seven all told with six deaths, one of the deaths was due to tetanus. If this is excluded from the list it gives seventy-six cases with five deaths—a mortality of 6.5 per cent. These wounds were due to all kinds of fire-arms including large- and small-caliber hand weapons, shell fragments, and shrapnel.

There were ninety-five gunshots of the knee-joint in the Anglo-Boer War with a mortality of 4.2 per cent. Amputation was performed in 11.5 per cent. of the cases, all of which were injured by shell fragments, and according to Stevenson the fatalities were confined to septic cases from severe shell fractures. We can surmise from this report that the other knee-joint injuries in which no deaths occurred resulted from hits by the projectiles of hand weapons, mostly reduced-caliber Mausers. This evidence agrees with our experience at the battle of Santiago. Out of seventeen cases of gunshot injury by the reduced-caliber Spanish Mauser there was not a death, fourteen of the men hit recovered so that they were restored to duty, and three were discharged on surgeon's certificate of disability or otherwise disposed of.

The results after gunshot of the knee-joint by reduced-caliber bullets, and the use of modern methods of treatment point in a most striking manner to the beneficence which has come from antisepsis and the humane injuries from steel-jacketed bullets of the modern military rifle.

Conservation in the wars of the present day should be practised in all cases in which the lesion of the knee has resulted from reduced-caliber bullets. This rule has been adopted as a result of observation of the nature of the lesions inflicted in war, and in the experimental field as well. The humane character of joint wounds, especially those of the knee, was foretold long before any war was fought with the new armament, and the work of the experimenters, which was so unjustly assailed by cities here and there, is no where more significantly brought out than we find it in the knee-joint.[1]

In the more simple cases no attempts at exploration should be made except for pieces of clothing or foreign bodies. Wounds of the patella alone are generally in the nature of a perforation and when fragmented the fragments are usually well held together by ligamentous tissue so that no surgical operation is required. In so far as the patella alone is concerned, the treatment is the same as practiced in shots which in-

[1] Report S. G., U. S. A., for 1893.

clude the synovial membrane or the osseous tissues of the joint proper.

When splintering and fragmentation of the ends of the tibia and femur are marked as shown by palpation it may become necessary to explore the joint for the removal of loose pieces of bone. This should be done by laying open the joint or by enlarging the wound of exit. If it is necessary to obtain sufficient room for purposes of diagnosis, an incision may be made on one or the other side of the patella, or a horse-shoe flap, convexity downward, should be raised, as recommended in formal excision of the knee. After dividing the ligamentum patellæ, the lateral and crucial ligaments, ample room will be found both for purposes of diagnosis and such operative interference as may be deemed necessary. After removing loose pieces of bone, lodged missiles, or other extraneous matter, the synovial sac and wounded surfaces should be irrigated with a weak antiseptic solution, the incised surfaces should next be brought together with appropriate sutures, and the necessary drainage provided for. The latter should remain in place from thirty-six to forty-eight hours. The limb should next be dressed and immoblilized upon a fenestrated wire or plaster-of-Paris splint.

If suppuration supervenes prompt incision and ample drainage will be required. If the case becomes septic, and shows no signs of improvement the surgeon will have to be guided largely by the evironments at hand. Where persistent and watchful care cannot be maintained as in enforced transport, the patient's chances will be better, if amputation is resorted to in the lower third of the thigh.

Anchylosis more or less complete is the rule in knee cases that recover after extensive comminution, or in cases complicated by suppuration.

Primary excision of the knee has never been a favorite operation in military practice. Otis, MacCormac and other noted surgeons do not recommend it. It should only be resorted to in the case of shell wounds with much fragmentation, in patients who positively refuse amputation. The old-time death rate from excision of the knee was largely from causes which are at present partly avoidable. In thirty-two recorded cases by Otis in our Civil War the mortality was 86.6 per cent. In other wars in the preantiseptic era the mortality ranged as high as 90 per cent. We have no statistics to show the results of excision under modern surgical conditions, but we have reason to believe that formal primary excision of the knee under proper environment may yet find favor in military practice.

Intermediate and Secondary Excision.—The fatality for excision in the intermediate stage was very great in the Civil War, only one recovery having been recorded in thirteen cases. The operation would doubtless be as fatal now but it is no longer recommended. Secondary amputation affords a far better chance of life. Secondary excisions find no more favor in military than they do in civil practice. The operation was done in two instances in the Spanish-American War with one recovery.

Primary amputation for injury to the knee-joint is only recommended in cases of extreme traumatism of the bones, soft parts and large vessels. Such injuries are usually sustained by shell fragments, and the patients more often die of shock and hemorrhage before reaching hospital care. The limb should be amputated through the joint or the lower third of the femur depending upon the amount and condition of the material for flaps. Statistics favor amputation at the latter point.

Gunshot Wounds of the Ankle-joint.—Among war wounds of the foot by gunshot, those confined to the ankle-joint aggregate one-third of the whole. Like most of the wounds of joints, gunshot injuries of the ankle are divided into those of the articulation without and with bone involvement. The former were designated under the term peri-articular wounds by Otis, of which there were thirty-seven cases in the Civil War, and 1711 of those with bone lesion. The peri-articular wounds, as designated by Otis, included injury to the tissues immediately surrounding the joint, like the vessels, nerves, tendons, and malleoli, without involving the joint cavity, and also cases in which the synovial sac of the joint was penetrated without bone lesion. He does not state how many of the thirty-seven peri-articular wounds were of the latter class. We have demonstrated experimentally on the cadaver that it is possible for a reduced-caliber bullet to penetrate the synovial sac transversely in front or behind on a line with the articular surfaces of the tibia and astragalus without injuring bony parts. On account of its superficial position, wounds of the synovial membrane of the ankle alone are generally admitted to be of rare occurrence, much more so than we find in either the shoulder, hip, or knee.

Gunshot Fracture of the Bones of the Ankle-joint.—The sectional area and velocity of the projectile will have great influence upon the osseous lesion in gunshot of the ankle-joint. The projectiles of the days of the Civil War inflicted injury that was more often marked by comminution, detached fragments, and extensive laceration of

the ligaments, tendons, etc., about the joint. Wounds of the *astragalus* by reduced-caliber bullets generally groove its superior, inferior, and lateral surfaces with few fissures, the latter being more often subperiosteal or sub-cartilaginous. When the body of the bone is hit the lesion is marked by a clean-cut perforation in the mid ranges. If the projectile is animated by a high velocity, the perforation will be attended with fissures extending in the substance of the bone, and when the bullet makes an impact at its maximum velocity the bone may be pulverized into minute fragments, the wound of entrance and exit being filled with bony sand. The lower end of the *fibula*, viz., the *external malleolus*, which consists of epiphyseal tissue, may be grooved or perforated with or without fissures extending into the joint. The bone opposite the joint higher up is very hard and brittle. Shots at this point in the fibula are apt to show considerable comminution involving the joint cavity. Shot injuries located in the joint end of the *tibia*, viz., in the epiphyseal tissue which includes the lower end of the internal malleolus and about 1/3 inch of the lower end of the bone proper, are prone to show the same tendency to clean-cut perforation that one observes in the joint ends of bones generally, but lesions in this limited area are not often seen. The bone involvement generally includes the tibia above the epiphyseal line where the compact bone is hard and the resulting lesion will show long fissures extending upward and downward into the joint. The amount of comminution or fragmentation will be proportional to the sectional area of the projectile and the amount of energy delivered on impact.

Lesions from shrapnel and shell fragments will generally be extreme in character and those from the latter especially will require immediate amputation as a rule.

The treatment of gunshot of the ankle will be taken up under *conservation, excision and amputation.*

Conservation.—About the time of our Civil War military surgeons generally followed the teachings of Larrey, Thompson, Guthrie and others which favored amputation almost exclusively in gunshot of the ankle. The wounds of those days showed characteristics that favored the development of sepsis, and, in a location so beset with dirt as the ankle, the dangers of the virulent infections were especially marked. Guthrie, in his treatise on Gunshot Wounds, states that "Wounds of the ankle-joint from gunshot are extremely dangerous, and in general require amputation." Thompson, in his report of observations, etc., after the battle of Waterloo, states that "Wounds in which musket

balls have passed through or lodged in the ankle-joint almost all require immediate amputation. These injuries by giving rise to high degrees of inflammation . . . . . not infrequently prove fatal. Among a great number who had survived the fever we saw but few in whom secondary amputation was not required, and in the cases requiring it this operation was far from being so successful as the primary amputation had been." The expressions of Larrey are all to the same effect. Our surgeons in the Civil War avoided conservation for similar reasons. In 1711 gunshot fractures of the ankle-joint reported by Otis but 518 were treated by this method. Generally the less severe cases were selected for the conservation method and even then the mortality rate was 19.5 per cent.

Among those who recovered from gunshot injury of the ankle after conservation in the preantiseptic era the results on the score of utility of the foot and limb were generally bad. The foot was more often ankylosed in the tibio-astragalian articulation and oftentimes, of more serious import, the ankylosis extended to the astra-calcanian articulation. There were deviations of the foot laterally or antero-posteriorly, the loss of tendons, necrosis, and long-continued inflammation in and about the tissues of the joint, persistent swelling and pain were among the remote disabling effects that made life more or less of a burden.

We have reason to expect better results hereafter under modern conditions. Still, as already stated, wounds in the ankle are located in rich soil for the development of septic microbes. In spite of the ample preparation that a great civilized government can make against the occurrence of sepsis in war wounds, infection occurred in twenty-eight out of the forty ankle-joint wounds reported from the Anglo-Boer War.[1] It is, however, gratifying to note that there was no death reported. Thirteen of the cases were marked by perforation, and nine among these were aseptic. They all made rapid recoveries under a conservative mode of treatment, but the majority showed some limitation of movement when invalided home. The removal of bony fragments among the thirteen cases exhibiting perforation was at no time required. Incisions were made in two cases, and a lodged ball was extracted from the substance of the astragalus in one. In twelve other cases operative treatment was resorted to for the removal of fragments of either the tibia, fibula, or tarsal bones. Eleven of these

[1] Gunshot Wounds of Joints by Lt.-Col. S. Hickson, R. A. M. C., in Stevenson's Report. Harrison & Sons, St. Martin's Lane, London, 1905.

cases were septic. There was considerable limitation of movement in some of the cases and absolute fixation in others.

The Surgeon-General, U. S. Army, for the four years 1898 to 1901, which includes the period of the Spanish-American War and Philippine Insurrection, reports twenty-six gun-shot wounds of the ankle-joint with two deaths. Eleven of the men were restored to duty, and thirteen were discharged on surgeon's certificate of disability. They were all treated conservatively with one exception, in which amputation became necessary. We may take the cases of the Spanish-American and Anglo-Boer Wars as an index of the results we are to expect in the majority of ankle-joint injuries hereafter under modern conditions. Conservation is indicated in the large majority of the cases, viz., in all except those in which the bones and soft parts have suffered such extreme traumatism as to necessitate immediate amputation. The rule of treatment now is to dress the wound antiseptically and to employ fixation at once. If fragments have to be removed this can usually be done through the exit wound, as it is larger and, when necessary, it can be incised to give more room. Only loose fragments should be removed. Severed tendons should be united by catgut or silkworm-gut suture. The wound should next be irrigated, and a drain to remain thirty-six to forty-eight hours put in place.

Fixation is best accomplished with plaster of Paris. The splint should extend from above the knee to the toes to properly immobilize the tibia and fibula. Plenty of window space opposite the ankle should be cut away to permit easy access to the wounds for redressing.

When the wound becomes infected, the inflammatory process will generally be arrested by establishing good drainage through free incisions, and the use of frequent irrigations with germicide solutions of a necessary strength once or twice daily. The after-treatment in the way of massage, movement of the toes, rubbing, and faradization of muscles will do a great deal toward restoring the use of the ankle.

Excision of the Ankle-joint.—This operative measure is only mentioned here to be condemned. It finds no place in either the primary, intermediate or secondary stages of ankle-joint lesion from gunshot. In addition to the fact that the results as far as the utility of the limb were extremely bad in our Civil War, according to Otis, the mortality of excision of the ankle was one-third greater than that observed after the conservative plan of treatment. The operation was not popular in former times. Otis records but thirty-three cases in the Civil War with nine deaths—a mortality of 29 per cent. The

results in the Fanco-German War out of fifty cases gave an aggregate mortality of 43 per cent. In the recoveries recorded by Otis the greater number suffered from painful and swollen joint; fistulæ were not infrequent, and the patients almost invariably had to walk with the aid of crutches. As a general result, in excision of this joint, the foot is often turned in or out, or it is left in a state of equinovarus; the toes are deformed, and walking is not only painful but uncertain. Finally the results as to restoration of function are such that amputation in the lower third of the leg has hitherto been considered preferable. There is no account of excision of the ankle-joint in either the Spanish-American or Boer War.

Amputation.—We have already indicated the conditions that demand primary amputation. They relate to extreme traumatism of bony and soft tissues with no hope of recovering the use of the ankle-joint or foot. These injuries are more often the result of hits by shell fragments, or wounds from shot-guns at close range, and they can also result from the effects of the modern rifle when it is discharged at contact or near by. Hickson[1] reports eleven cases of amputation out of forty injuries to the ankle-joint in the Boer War. The operation, as a rule, was rendered necessary on account of septic conditions associated with comminuted fractures. Shell wounds figured in five of the cases and three of these were done on the field, but reamputation was necessary later on, from which the reporter lays emphasis upon the mistake which is often made of performing primary amputations at the front.

Secondary amputation will be indicated when infection has thwarted attempts at conservation. The limb will have to be sacrificed at a point marked by sound tissues.

[1] Op. cit.

CHAPTER XII

Gunshot Injuries of the Diaphyses of the Long Bones

The military surgeon is especially interested in gunshots of the diaphyses on account of their frequency, their varied character, the difficulties which they offer in transport, and finally, because they always figure among the serious wounds.

Fig. 137.

Fig. 138.

Fig. 137.—Radiograph showing oblique fracture by contact of Mauser bullet against outer side radius, from Spanish American War. (Borden.)

Fig. 138.—Radiogram from Turko-Balkan War, 1912–13. Oblique fracture from very slight guttering of humerus in a Turkish Infantryman by Bulgarian rifle bullet at Lulu Burgas 1200 meter range. War College collection.

Contusions.—Lesions of this class are the result of direct injury by grazing, glancing or direct impact againt bone from bullets or pieces of shell. The older works, like those of Guthrie, McLeod,

Longmore and others made no reference to this form of injury. Lidell[1] in our country was among the first to prominently call attention to such cases. He points out a fact observed by others since, that contusion of the diaphyses in the lower extremities is more prone to lead to necrosis and other bone complications than contusion of the diaphyses in the upper extremity, because the latter are more richly endowed

Fig. 139.—Radiogram from Turko-Balkan War, 1912–13. Oblique fracture by Turkish rifle bullet at Burnar-Hissar, Oct. 30, 1912. War College collection.

Fig. 140.—Radiogram from Turko-Balkan War, 1912–13. Transverse fracture by Turkish Shrapnel. Fragments of shrapnel ball lodged near elbow-joint.

with blood supply. None of the cases cited by Lidell include the humerus, for instance, and Otis calls attention to the fact that our army medical museum collection possesses but two examples of contusion in the humerus with other evidences of bone lesion, while such instances are not uncommon in the femur and tibia. Six of Lidell's thirteen cases were due to spent bullets lodged against bone and were removed through the wound. Five cases resulted from glancing bullets, one a grazing shot. One resulted in amputation, five died, and seven made more or less complete recoveries.

[1] Contusion and Contused Wounds of Bone with an account of thirteen cases by John A. Lidell, Surgeon U. S. Vols., Am. J. Med. Science, Vol. L, 1865.

Contusion of bone will be less likely to occur from the effects of the modern bullet unless it has lost its remaining velocity before impact, but it may occur from glancing shots at high velocity. Experiments, and observations in war have shown that the slightest contact by a bullet travelling at high velocity conveys a vibratory force to the bone of sufficient intensity to cause complete fracture. Such fractures are often attended with long fissures radiating some distance from the point of impact (Figs. 137, 138, 139 and 140). Whether this vibratory force is sufficient to cause contusion short of fracture when the bullet passes near a bone just short of contact has not been noted so far.

The lesion in contusion of bone shows effusion of blood under the periosteum, the bone has lost its blood supply and in cases of direct injury by the ball there may be more or less destruction of the superficial part of the bone which adds to the existing lesion. The element of contusion and hematoma described augments the tendency to the development of infection, in which case, periostitis and ostitis are prone to occur, and when they do unless they are promptly and properly treated, terminal bone troubles, like necrosis with exfoliation of sequestra, or, worse still, osteomyelitis is liable to develop. In cases of injury adjacent to bone, whether fracture is present or not, if infection sets in, with the accompanying train of symptoms pertaining to inflammation in bone, the surgeon should regard the case as one of the acute bone lesions and treat it accordingly.

Treatment of Contusion.—To forestall sepsis is the prime indication in contusion of the diaphyses of the long bones. This is done by the use of antiseptic solutions upon the wound and the adjacent skin, or preferably painting with Tincture of iodine before applying the first clean dressing. The projectile when lodged against bone should be removed as soon as it has been properly located. The wound should next be thoroughly irrigated with a weak antiseptic solution and then immobilized. If the temperature rises, with other symptoms of acute inflammatory process in bone, a free incision should at once be made down to the latter including the periosteum, to insure perfect drainage. If pus is found or if the pain and temperature continue, the compact bone at the point of injury should be trephined down to the medullary canal. If osteomyelitis is present, trephining at several points may become necessary. When the measures mentioned prove of no avail

and the symptoms persist, amputation should be performed at the joint next above the lesion. In a case of septic osteomyelitis of the femur Major Powell C. Fauntleroy, U. S. Army, and the author were able to arrest the disease process by amputating at the junction of the middle and upper thirds of the femur, after which the medullary canal remaining was curetted and swabbed with pledgets of lint on a probe, saturated with a solution of bichloride of mercury 1–1000.

Gunshot fracture of the diaphyses of the long bones may be divided into (1) simple fractures and (2) compound fractures.

Simple fractures were more frequent formerly as a result of impact against a bone by slow-moving shells or pieces of hollow shells of moderate size. Such fractures were also observed to occur from the large rifle projectiles striking at low velocity against a bony part with clothing or part of the equipment of the soldier intervening between the skin and the bullet. The force of impact in these cases more often caused contusion of soft parts. The infrequency of simple fracture from such traumatisms may be estimated by the fact that Otis with his vast opportunities to collect accounts of all kinds of fractures from our Civil War mentions but nine cases of simple fracture without open wounds, and five of these occurred in the humerus. The amount of fracture and contusion of soft parts will depend on the volume and the force of impulse which is exerted by the projectile. The fractured bone may show comminution or simple fracture, and in the long bones multiple fractures have been noted. Otis gives the history of a case in a sergeant of artillery who was struck at the first battle of Bull Run "by a 12-pound shot which fractured the humerus at three different points, but did not even bruise the skin."

Simple fracture of the diaphyses of all the long bones as well as those of the metacarpal and metatarsal bones have been noted in the literature. It is doubtful if simple fracture with the use of the new armament will be noted as frequently hereafter. Large shot are mostly used against material now, and except on board men of war in naval combat and during siege operations they do not figure among the causes of war wounds. The treatment of simple fracture from gunshot is the same as that of simple fracture from other causes.

(2) **Compound fractures** by gunshots are marked by an open wound of the soft parts leading into the foyer of fracture. The lesions in these osseous injuries were described in Chapter II, which deals with the characteristic features of gunshot wounds by different kinds of pro-

jectiles and they will not be referred to here except to state that the amount of traumatism in every fracture is coincident with the velocity of the projectile, its sectional area, and the resistance offered by the bone at the point of impact. The degree of traumatism will include grooving, perforation with short or long subperiosteal fissures, comminution with detached fragments, and fissures which may extend above and below the fracture, as far as the adjacent joints. Gunshot fractures of the diaphyses are numerous in war hospitals. They form 12 per cent. of all war wounds (Fischer). According to Otis those of the bones of the leg constitute 31 per cent. of all the fractures of the long bones; the humerus 28.4 per cent.; femur 22.6 per cent. and the bones of the forearm 17.9 per cent.

Follenfant[1] reports upon the variety of gunshot fractures exhibiting explosive effects in the Manchurian campaign, from which we find that operative measures for the removal of bone fragments were not numerous. The Karbine statistics for 1904 record the removal of fragments in 184 cases out of 2845 fractures of the extremities. The fractures of the diaphyses showed long fissures on X-ray plates, as a rule. The infections were frequent, but not grave, and the amputations rendered necessary were comparatively few in number, not exceeding 5 per cent. for all fractures of long bones. Of thirty-six cases of tetanus observed at Karbine in 1904 thirty-three occurred in gunshots of the extremities. The mortality after gunshot fractures was very small. Of 2845 cases only thirty-nine deaths are recorded and sixteen of these occurred among 478 gunshot fractures of the femur. The rule of treatment was almost entirely conservative.

Treatment of Gunshot Fractures of the Humerus.—Of eighty-seven gunshot fractures of the humerus reported by the Surgeon-General[2] from the Spanish-American War and Philippine Insurrection 1898–1901 inclusive, there were five deaths or a mortality of 5.7 per cent. Twenty-one of the eighty-seven cases were due to bullets, kind not stated, thirty-two were caused by Spanish Mausers of reduced caliber, seven by Krag-Jorgensen bullets, four by revolver bullets, seventeen by Remington rifle bullets, one by shrapnel ball, one by piece of shell, two by pieces of steel and slugs. The disposition of the cases was as follows: Thirty-nine or 45 per cent. were restored to duty, twenty-nine discharged for disability and twelve were otherwise discharged the service. There were ten amputations performed, one resection, frag-

[1] Op. cit.

[2] Annual Reports, S. G., U. S. A., 1898–1902.

ments of bone were removed in several cases and incision for drainage was done in one case. There is no record of the number of lodged balls available.

Hickson[1] in his report of cases in the South African War gives notes of eighty-three fractures of the humerus caused by every variety of projectiles. Forty-two of the eighty-three cases were septic. Removal of fragments was done in twenty-two cases in every one of which sepsis was present. There were thirteen amputations or an amputation rate of 15.6 per cent. and sepsis was present in all of these. There were but three deaths out of the eighty-three cases, a mortality of 3.6 per cent.

The mortality for the two groups cited, those in the Spanish-American and Boer Wars, speaks well for the modern methods of wound treatment in war, and the beneficence which comes from the use of reduced-caliber rifle bullets. More than half of our cases were due to this bullet although the records ascribe many of the wounds due to "bullet" in the returns, a convenient term, employed by surgeons generally. For instance of the eighteen cases from the battle of Santiago, twelve are put down as due to bullets when as a matter of fact we know that they were nearly all due to injury by the Spanish Mauser.

Conservative Treatment.—Conservation should be practised in all gunshot injuries of the humerus, except those in which the necessary blood and nerve supplies of the arm have been destroyed, regardless of the amount of comminution. In preantiseptic times surgeons often sacrificed arms on account of extensive bone lesion that are prefectly amenable to treatment now. Under our present method of wound treatment, we look for consolidation of fragments, however numerous, provided they are attached to periosteum or soft tissues which give them blood supply. We look for consolidation even in cases where there is loss of bone substance in continuity for 1 or 2 inches. Nature will fill the gap with callus in time. To insure all these expectations on the part of nature it is necessary first of all to exclude sepsis, and the fate of the limb will depend upon the surgeon's ability to maintain asepsis. To this end the skin and wound are to be cleansed thoroughly by scrubbing with soap and water, and by irrigation with antiseptic solutions. To facilitate exploration the exit wound, which is usually larger, and near which the bulk of fragmentation is found, should be enlarged by incision when necessary. Frag-

[1] Op. cit.

ments which still adhere should be replaced as near as possible to their normal position, after they have been released from any entanglement with the soft parts, and those fragments which are entirely detached should be removed. In wounds showing explosive effects it is not unusual to find fragments buried in the tissues 2 and 3 inches from the point of fracture. The wound should be dressed antiseptically, a drain put in place to be retained twenty-four to forty-eight hours, and the limb immobilized, including both the shoulder- and elbow-joints with the fore-arm flexed at a right angle. Immobilization should be accomplished by the splints ordinarily used in surgical practice, but plaster of Paris as a fixed dressing should be given preference whenever it can be conveniently employed.

In the lesser degrees of fracture, and in aseptic cases especially, exploration with a view to removal of detached fragments will not be necessary. Beyond cleansing the skin near the wound, a clean dressing and fixation of the limb as above stated, there is but little to be done.

Hickson states that the most noticeable feature among the after-effects of the eighty-three cases from the South African War was the frequency of nerve injuries, especially the musculo-spiral. The large nerves were seldom cut by the projectiles, the lesions were a result of direct pressure by callus or fibrous bands.

Non-union in fractures of the humerus, which F. H. Hamilton and others of our great authors have so often noted in civil practice, is happily very infrequent in military practice. Of 2900 cases of gunshot fracture of the humerus in our Civil War Otis records but six cases of pseudarthrosis and two of these were after simple fracture. Neurdorfer[1] states that he has not met with a single case in all of his military practice as a result of shot fracture. Non-union in civil practice has generally been attributed to the difficulty of properly immobilizing the broken fragments. Sedillot[2] ascribed the generally uniform union of fractures after gunshots to the extent and activity of the osteogenetic process.

Excision in continuity was once advocated by military surgeons and during our Civil War it was practised more than any time before or since. In badly comminuted fractures the older surgeons indulged the hope that a formal excision would be attended with less danger than an attempt at conservation, but the faithful and costly

[1] Handbuch der Kriedschirurgie, 1872, B. II, S. 1179.

[2] Du Traitment des Fractures des membres par Armes a Feu Arch. Gen. de Med., Ser. VI, T. XVII, P. I.

attempts in our Civil War had the tendency to array the dictum of the profession against the practice, so that it is no longer advocated as an operative measure. Otis significantly calls attention to the fact that in the 696 cases of excision in continuity in our Civil War the aggregate mortality rate was 28.5 per cent. This mortality is 12 per cent. higher than that in a larger series of primary amputations in the upper third of the arm and nearly double that observed in 3005 cases treated by conservation. Among those who recovered after excision in continuity, one-third had "no bony union" or "false joint"; a number suffered consecutive amputation of the arm; and more still suffered ultimate exarticulation or amputation with a mortality of nearly 50 per cent. The remonstrance which Otis made to the operation was accepted by men like Ashurst, Hamilton, and Gross in this country, and MacCormac in England. Under our present mode of treatment we practise conservation in all the cases where excision in continuity was practised in the time of our Civil War. If we exclude sepsis from the foyer of fracture, callus will form to fill whatever gap may arise from loss of bone substance. Cases with loss of much bone in continuity can now occur only from shell wounds and from hand weapons when discharged at short range, producing explosive effects. Experience has taught us that such a wound treated conservatively by cleaning the field and the wound, removing loose fragments, and immobilizing the limb, is attended with less mortality than excision in continuity or a formal attempt to fill the gap by evening up the irregularity of the fractured ends with a saw, and then bringing the fragments together with wire, etc.

Primary amputation of the arm is only justified in hopeless destruction of soft parts, including the large vessels and nerves of the arm. The great value of the upper extremity to the patient's struggle for existence causes a surgeon to weigh well the nature of the injury and the condition of the patient, before he resorts to amputation. The loss of an upper extremity is of such moment to the patient that he is often willing to take a certain risk on his life before giving his consent. Aside from this objection to primary amputation the older surgeons were fully cognizant of the wonderful resources of nature to restore a badly comminuted arm to its former utility. Non-union was seldom noted, and many of the military surgeons like Guthrie and Longmore were loath to sacrifice an arm, in spite of extensive comminution, including injury to the brachial artery.

These views on amputation were entertained by the majority of

the Confederate surgeons in our Civil War.[1] They were largely guided by the following advice from Longmore: "Unless the bone be extremely injured by a massive projectile, or longitudinal comminution exist to a great extent, especially if it also involves a joint, or the state of the patient's health be very unfavorable, *attempt should always be made to preserve the upper extremity after a gunshot wound.*" These views held by the majority of the world's surgeons were not shared by those of our army between 1861–65, during which period, out of 8245 gunshot fractures of the humerus unattended by primary injury of the shoulder- or elbow-joints, there were 3259 primary amputations of the arm in the continuity of the humerus with a mortality of 18.4 per cent. The record shows that the surgeons in the Union Army practised primary amputation in 39.5 per cent. of the 8245 gunshot fractures of the humerus. Considering the consensus of opinion against the practice before and since, the percentage is large, but Otis offers explanations that go far to exonerate the field surgeons of the charge of sacrificing limbs without cause. Certainly many of the primary amputations that were performed were absolutely necessary on account of extensive lacerations by cannon shot with injury to vessels and nerves. There still remained a very large number in which amputation was performed because of extensive comminution of the shaft by the projectiles of hand-weapons. Considering the dangers of sepsis which then prevailed, and the unfavorable environments which precluded the adoption of proper conservative efforts, on account of the absence of adequate hospital facilities, and the absence of safe and suitable transportation, Otis states that the surgeons very properly adopted what John Bell called "an argument of necessity as well as of choice, and limbs that in happier circumstances might have been preserved had often, in a flying army or a dangerous campaign, to be cut off; . . . . . it is less dreadful to be dragged along with a neat amputated stump, than with a swollen and fractured limb, where the arteries are in constant danger from the splintered bones." The plan of amputating amid such surroundings sacrificed many limbs, but at the same time we must admit that it was attended with the saving of many lives.

According to Chauvel and Nimier, Legouest, and Delorme, a

[1] Warren (E). An epitome of Mil. Surgery, 1863, p. 372, and Chilsolm (J J). A Manual of Mil. Surgery, 1863, p. 386, and also a Manual of Military Surgery prepared for the use of the Confederate States Army, by order of the Surgeon-General, C. S. A., Richmond, 1863.

comminuted fracture of the humerus complicated by injury to the brachial need not necessarily be a cause for amputation in all cases. For instance, when the brachial is severed sufficiently low to insure the supply of the superior profenda, a policy of expectancy can be followed, watching meantime for the first sign of the occurrence of gangrene; but Delorme would do an amputation when the artery is severed as stated, if the anastomotica magna is also wounded. In other words, these authors believe there is no indication for amputation as long as the location of the wound in the branchial is such that its collateral circulation is not endangered.

In the confusion and pressure for time and trained assistants that prevail in field conditions, the attention which it is necessary to bestow on a gunshot fracture with injury to the brachial in accordance with the foregoing rules, it not justified. The point made by these authors should, however, be borne in mind as it may exceptionally find application under more favorable environments.

Secondary amputation more often became necessary in preantiseptic times on account of secondary hemorrhage, persistent infection in bones and soft parts, and for remote effects such as useless and painful limbs. Out of the 5456 amputations of the humerus for shot injury in our Civil War there were 411 secondary amputations with a mortality of 27.7 per cent.

Secondary amputations will be far less often noted in future wars. The success which modern surgeons obtain in saving limbs will no doubt cause useless limbs to become one of the most frequent causes for secondary amputation. It certainly forms one of the frequent causes of amputation in Soldiers' Homes.

Gunshot Fracture of the Forearm.—Gunshot wounds of the left forearm are more frequent, and they are attended with greater mortality than gunshot wounds of the right forearm (Chauvel et Nimier). Without offering any reason for the latter, these authors make the further statement that gunshot wounds of the left leg are more frequent than those of the opposite side, and that they are also attended with greater mortality. From 10 to 15 per cent. of all fractures in war are noted as fractures of the bones of the forearm. The ulna and radius may be fractured together or independently. In shots disposed anteroposteriorly or *vice versa* but one bone is usually fractured, while shots directed obliquely or transversely are most apt to be attended by fracture of both bones. The amount of fracture may range from guttering and partial fracture to complete fracture.

The bones of the forearm, except at their epiphyseal ends, are hard and brittle, furthermore the compactsubstance is thin, all of which accounts for the limited foyer of fracture and fissuring usually observed in these bones. The area of fracture may be extensive at times as observed

Fig. 141. Fig. 142.

Fig. 141.—Fracture showing comminution with detached fragments involving radius and ulna by bullet from .45 cal. Colt's new service revolver at 75 yards, in cadaver. Bullet and metallic fragments from it are lodged. Army Med. School collection. Gibbs X-ray Laboratory.

Fig. 142.—Fracture with detached fragments from .30 cal. Krag-Jorgensen bullet as a result of slight grooving on internal border of bone. From Philippine Insurrection. Army Medical School collection.

in fractures involving the two bones. In such cases, the first bone hit fragments, and its spiculæ, acting as secondary missiles, make an impact with the projectile on the second bone causing more than the usual amount of bone comminution and injury to soft parts (Figs. 141, 142 and

143). The explosive type of fracture is especially common in the ulna as a result of its subcutaneous position, and for a like reason the same explosive type is more commonly exhibited in the lower third of the forearm, when fracture of one or both bones occurs. On account of the proximity of the arterial vessels to bone, injury to blood-vessels and

Antero-posterior. Lateral.

FIG. 143.—Radiogram showing two views in case of Pvt. Dennis M., late pvt. Co. "G," 9th U. S. Inf., wounded at Tiensin, China, during Boxer Rebellion, July 13, 1900, by large caliber lead bullet at 150 yards. Skiagram taken Feb. 1901. Remote effects: paralysis of wrist and hand with pain in forearm and elbow. Very slight movement in extensor tendons of fingers. Marked impairment of hand and fingers in the distribution of radial and median nerves. Army Medical School collection.

hemorrhage, are among the frequent complications of gunshot fracture in the forearm. Injury to the interosseous arteries is especially common.

From the statistics of the Spanish-American and Boer Wars we find as follows: Of 114 cases of gunshot fractures of the forearm

reported by the Surgeon-General, U. S. Army, for the years 1898–1902,[1] thirty-six were caused by reduced-caliber bullets, mostly Spanish Mausers, sixteen by Remington bullets, forty by bullets, six by revolver bullets, two by slugs, two by shell, two by cannon, three by explosion of powder, one by shrapnel, one by explosion of a cartridge. The large majority of these fractures appear to have resulted from the projectiles of hand weapons. Ten of the cases or 8.3 per cent. suffered amputation, with one death—the only death recorded. Bone fragments were removed in ten cases, resection was done in one case, and lodged balls were removed in five cases. Fifty-six of the cases or 49.1 per cent. were restored to duty, forty-four were discharged for disability, while the remainder were mustered out, discharged by order, etc.

Of sixty cases of gunshot fractures of the forearm reported by Hickson[2] from the Anglo-Boer War, none terminated fatally. The radius was involved in twenty-seven cases, the ulna in eighteen, and both radius and ulna in fifteen cases. Of fifteen cases exhibiting fracture of both bones twelve were septic. Amputation was resorted to in three cases.

Of the twenty-seven cases of fracture of the radius alone, sixty per cent. were septic, there was one amputation for gangrene from injury to the brachial at its bifurcation. Fragments of bone were removed in about 40 per cent. of the cases.

Of eighteen cases of fracture of the ulna, all but two were septic. Amputation was necessary in two cases, one as a result of gangrene, the other as a result of extreme injury to bone and soft parts.

Treatment.—With our modern methods of treatment conservation, with very few exceptions, is the rule of treatment in all gunshot fractures of the forearm. A limb is never condemned to amputation except in cases of extreme traumatism of the soft parts, bones, and laceration of nearly all the principal arteries. During our Civil War out of 5194 gunshot fractures of the forearm, the precise seat of injury was specified in 4334 cases, and of this number the ulna and radius were fractured in 1291 cases. There were 1007 primary amputations with a mortality of 9.5 per cent. and the majority of these were for gunshot fracture of both bones. Excluding one hundred and forty-three amputations practised for extreme traumatism as a result of injury by cannon balls, shells, or fragments from torpedoes,

[1] Annual Reports of the Surgeon-General, U. S. Army, for 1899–1903.
[2] Op. cit.

we have a total of 854 instances of amputations which were done on account of lesions arising from the projectiles of hand weapons. There were also nearly 1000 excisions done for injury to the bones of the forearm, "of which a very small proportion were attended by absolute destruction of the parts by large projectile or explosions, or by injuries of all the principal blood-vessels or nerves." This large proportion of amputations and excisions was subsequently condemned by Otis as unnecessary, the excisions added to the mortality and seldom improved the utility of the limb among those who survived. This mania for operative work is ascribed by Otis to the number of "inexperienced medical officers, hastily summoned to the field in emergencies." Otis shows that the greater number of operations were performed during the earlier part of the war and that mature judgment and experience condemned the practice later. Amputation, except for the reasons already mentioned, was frowned upon by all of the noted authorities at that time, and with our present methods of wound treatment conservation finds additional emphasis. Conservation should always be practised in gunshot fracture of one bone, although complicated by wound of one or the other of the larger arteries. Delorme even advocates conservation in cases where both arteries—the ulnar and radial—are involved, provided the interosseous arteries are not injured. The rule is never to resort to amputation except in those cases where both bones are fractured and the large arteries are severed, or when extensive traumatism of the bone and soft parts occurs from shell fragments, implicating also the median and ulnar nerves.

When conservation is decided upon, bleeding vessels should be tied, severed tendons and nerves should be sutured, and all detached fragments removed. The wound should then be irrigated with an antiseptic solution, drainage provided for and the limb immobilized. The latter can be accomplished by straight forearm splints or preferably plaster of Paris. Massage of the fingers, wrist and elbow should be practised early during convalescence to preserve the utility of the arm and hand.

Excision in the continuity of the bones of the forearm for gunshot was never considered a favorite operation in military surgery. Of 965 cases of excision at all clinical stages in our Civil War the mortality was 11.2 per cent., while in 2943 cases treated by expectation it was but 6.4 per cent. In addition to the objection on the score of mortality, Otis states that he was unable to find a single instance with a satisfactory result, concerning the utility of the limb.

The operation has found no adherents in recent times. Conservation, removal of detached fragments, and rigid antisepsis render excision at any time entirely unnecessary.

Amputation.—We sacrifice the limb in gunshot of the forearm when both bones are fractured, and the larger arteries are severed, or when extensive traumatism of the bones and soft parts occurs from shell fragments implicating the median and ulnar nerves. Ten amputations of the forearm for gunshot fracture are reported from the Spanish-American War with one death. Five cases suffered amputation in the Anglo-Boer War with no death.

Gunshot Wounds of the Hand.—Out of 105,786 shot wounds during the last year of our Civil War Otis found that 5.3 per cent. were of the metacarpus and 4.9 per cent. were of the phalanges or fingers. Out of a total of 11,369 gunshot wounds of the hand during the whole of the same war there was an aggregate mortality of only 3.1 per cent. The modern notion that gunshot injury of the hand is prone to the development of tetanus is rather negatived by Otis' statistics, since only twenty-four cases supervened out of the large series referred to. The occurrence of tetanus from gunshot of this region has received special attention by the surgeons of this country in connection with toy-pistol injuries to which we have already referred.

The character of the lesion in the metacarpal bones by the modern rifle bullet consists of comminution to a greater or less extent with an occasional example of grooving or perforation. Transverse shots across the metacarpal bones of the hand, and also shots similarly disposed across the metatarsal bones of the foot, are prone to show particles of lodged metal on X-ray plates. This fact has been commented upon by experimenters and by surgeons who have described the characteristic features of gunshot wounds in recent campaigns. It has seemed strange that a resistant projectile, armored with a steel jacket that usually withstands the hardness of the long bones like the femur and tibia, should disintegrate on impact against a number of small thin brittle bones, like those of the metacarpal in the hand. The reason for this seems to lie in the fact that the bullet is deflected for the want of proper support after passing through the first or second bone and that, as it commences to make an irregular impact, when still possessed with sufficient momentum, the pressure which is exerted on the sides of the bullet causes its nucleus to separate more or less from the jacket with a tendency to disintegration of the whole

bullet, hence the pieces of metal that remain lodged. Ordnance officers have seen the same thing occur in projectiles when fired against certain thicknesses of armor plate placed one behind the other, and disposed at short intervals. Projectiles that find proper support while penetrating a target of solid metal hold their original shape, but

FIG. 144.—Radiogram in case of James M. Denn, 95th Regiment Penn. Vols. shows lodged Minie ball in palm right hand since the battle of Spottsylvania, May 10, 1864. Ball entered dorsum 2 cm. behind metacarpo-phalangeal joint opposite point of lodgment. Ball lies imbedded in a cyst which has developed from the synovial sheath of the flexor tendon of the thumb. Ball removed by the author at the U. S. Soldiers Home, June 26, 1902. Missile was loose in a thick sac under palmor fascia. Sac contained about 1 ounce of hemorrhagic fluid, the blood being no doubt the result of frequent traumatisms from shaking the hand violently near the ears of his friends to cause them to hear the ball rattle in the cyst. The succussion sound made by the loose ball and the fluid in the unyielding sac was very perceptible to the sense of hearing. Radiogram was taken June 26, 1902, 38 years after the injury. U. S. Soldier's Home Hospital Laboratory, Dr. A. B. Herrick, X-rayist.

they generally break up when fired against a target composed of a number of plates as above described.

The mortality from gunshots of the hand under modern conditions is very small. Out of 470 cases reported by the Surgeon-General, U. S. Army, for the years 1898–1902,[1] there were five deaths. One

[1] Annual Reports S. G., U. S. A., for 1899–1903.

of these was due to tetanus, one to septicemia, one from gangrene which necessitated amputation at the shoulder, and the other two were due to causes not related to the injury. Wounds of the hand are generally septic. Of thirty cases noted by Hickson in the Boer War twenty-six or 86.6 per cent. were infected.

Treatment.—The most rigid antisepsis should be used from the beginning. The application of a first-aid dressing alone should not be considered sufficient in gunshots of the hand. The whole hand

Fig. 145.—Radiogram in case of Pvt. A. Co—Reg—U. S. Army. Shot with .32 Winchester rifle at Ft. Custer, Mont., 1882. (1) Bullet and a fragment lodged near greater trochanter. (2) Suppurating sinuses marked by bismuth injections. Bullet removed by Col. Crosby, Med. Corps, U. S. A., at Soldiers Home, Sept. 1911. Army Medical School collection.

should be painted with tincture of iodine or thoroughly scrubbed with soap and water and the wound thoroughly irrigated with bichloride of mercury 1–2000. Detached spiculæ of bone should be removed, drainage provided for, and after the application of a clean dressing the hand and forearm up to the elbow should be immobilized. If sepsis sets in, the continuous arm bath will be of great service; and if suppuration is impending free incisions and thorough drainage should be practised early. In extensive comminution of

the phalanges and metacarpal bones the surgeon should make every effort to preserve as much of the injured part as may be consistent with even a partial degree of utility. The advantage of preserving one or more fingers, as, for instance, the thumb and one finger or the index finger alone, is of great value.

Gunshot Injuries of the Shaft of the Femur.—There were 6738 shot injuries of the femur in our Civil War, of which 162 were classed as contusions and 6576 as gunshot fractures.

Fig. 146.—A recent skiagram showing lodged conoidal bullet against bone in old soldier wounded in Civil War, 1861–65. Reported by Lt. Col. George DeShon, Med. Corps, U. S. Army. Army and Navy Genl. Hospital, Hot Springs, Ark. X-ray Laboratory.

Shot Contusion of the Shaft of the Femur.—The contusions of the femur from gunshots were more frequent than those of the humerus already referred to. Otis records that amputation became necessary in nine instances with seven fatal results, a mortality of 77.7 per cent., while the remainder 153 were treated conservatively without operation with a mortality of 22.8 per cent. (Figs. 145 and 146).

There is no reference to contusion from gunshots of bone in recent wars. The lesion is evidently more rare with the new armament, or the present method of wound treatment, which tends to keep wounds

aseptic, does away with the inflammatory complications that formerly unmasked the lesion. Still we might naturally expect a larger percentage of gunshot contusions with the use of the old, larger-caliber lead bullets, than from the highly penetrating rifle bullets of the present day, which seldom lodge.

Gunshot Fractures of the Shaft of the Femur.—Shot fractures of the femur occurred in 26.9 per cent. of all gunshot fractures, and they formed 2.3 per cent. of all wounds in our Civil War hospitals. The mortality in 6576 recorded cases was as follows: for the upper third 49.7 per cent.; middle third 46.1 per cent.; the lower third 42.8 per cent.

The foregoing statistics agree in the main with the results following similar injuries in the wars before the introduction of antisepsis and the change in armament.

In recent wars we have gathered enough data to show a marked change for the better in the outcome of gunshot fractures of the femur. There were 132 cases of gunshot fracture of the femur in the Spanish American[1] War with a death rate of 14.3 per cent.; and 170 cases were recorded for the Boer War[2] with a mortality of 17 per cent. Of the 132 cases from the Spanish-American War the projectiles of the hand weapons were responsible for 97 per cent. of the fractures, and at least 75 per cent. of these were the result of shots from the reduced-caliber rifles. Shell and shrapnel only caused two fractures each. The greater mortality in the British returns from the Anglo-Boer War was doubtless due to the greater number of severe fractures from artillery fire. Hickson states that "a considerable number were due to shell wounds . . . . . including the Vickers-Maxim." Otherwise the cases from the two wars were quite similar. They were inflicted in battle for the most part, and they received the same treatment and about the same care and attention. If we group the cases of the two wars together we have 302 cases of gunshot fracture of the femur which under modern conditions give a mortality of 15.8 per cent. By deducting this percentage from 46.2 per cent., which was the mortality of gunshots of the femur in the Civil War, we find the gratifying reduction of 30.4 per cent. in the mortality of gunshot fractures of the thigh under modern conditions as compared to the mortality in preantiseptic times.

Treatment by Conservation.—Under modern conditions the

[1] Annual Report S. G., U. S. A., 1899–1902.

[2] Lt.-Col. S. Hickson, op. cit.

large majority of gunshot fractures of the femur are treated by conservation. This mode of treatment is applicable in all cases except those attended by extensive comminution, laceration of soft parts, and destruction of the main vessels and nerves.

Until 1848, the treatment followed by military surgeons in fractures

FIG. 147.—Figs. 147, 148 and 149 show the happy results in a gun-shot fracture treated by modern conservative methods.

Pvt. Harvey B., 27th Co. U. S. Coast Artillery was shot at 100 yards range by the U. S. Army pointed, Springfield rifle, full-jacketed, bullet. A clean dressing and immobilization were employed at once. No infection ensued. Slight displacement of fragments, with 1 inch shortening. Limb is strong and serviceable. A slight limp renders patient unfit for military service. Discharged on S. C. D., at U. S. A. Lettermann General Hospital, Nov. 13, 1911. Fig. 147 shows femur immediately after injury. Figs. 148 and 149 give postero-anterior and side views of femur with 1 inch shortening at time of discharge. Reported by Major R. M. Thornburg, M. C., U. S. A., from Lettermann General Hospital.

of the femur was amputation in all cases. Doubtless the rule was established after mature experience in earlier times. It was the commonly accepted belief among surgeons then that all gunshot fractures of the femur ended fatally unless they were treated by amputation.

The ever-present factor relating to sepsis and its complications, as well as the gravity of the lesions incident to the use of the armament of those days, no doubt played a great part in the toll of deaths, and in the reason for the establishment of the radical treatment by amputation. However this may be, in 1848 it was pointed out by the surgeons of the French school, notably by Malgaigne, Velpeau and Jobert, that treatment by conservation had become preferable to treatment

Fig. 148.

Fig. 149.

by amputation. Of 4000 inmates in the hotels des Invalides, Paris,[1] 1814–21, there were but seven who had recovered after conservation for gunshots of the femur, while from 1847 to 1853 there were sixty-three inmates who had been cured after conservation, and during the same period but twenty-one who had suffered amputation for gunshots of the femur. Since then the plan of treatment by conservation has steadily gained in popular favor. Our Civil War affords statistics of the greatest value upon the results which just preceded the antiseptic era. Out of 6576 gunshot fractures 3467 were treated by conservation. For the latter the mortality for fractures of the upper third

[1] Delorme, Op. cit.

was 46 per cent.; the middle third 40 per cent.; the lower third 38.2 per cent., while the mortality following amputation was for the upper third 73.6 per cent.; for the middle third 53.3 per cent. and for the lower third 45 per cent.

The conservative treatment of gunshot fracture of the femur at the present time is very much the same as that already referred to in the case of the other long bones. Rigid antisepsis must be practised in all the details attending exploration. The latter is generally done by enlarging the wound of exit. All loose fragments as determined by digital examination should be extracted, and those which still adhere to periosteum or soft parts should be replaced as near as possible to their normal position. After bleeding has been properly checked the wound should be irrigated with a weak antiseptic solution, proper drainage should be employed for the next twenty-four to forty-eight hours, and the limb should then be dressed with a clean dressing and immobilized. The latter is most effective when it includes the pelvis, hip and foot. When transport is inevitable immediately after the injury, nothing takes the place of a well fitting plaster-of-Paris cast with window space opposite the wounds. This has some objections, however. The cast needs watchful care lest the bandage should constrict and cause unnecessary suffering. In the absence of plaster of Paris, splints of wire netting or a Hodgen splint which tends to obviate undue displacement of the upper and lower fragments is very popular with military surgeons. Sand bags and a long outside with a short inside splint and a Buck's extension will answer in the absence of something better. The great problem is to keep the limb immobile and to avoid sepsis. The first is met most effectually with a plaster cast, and the latter will require the unremitting attention of the surgeon. In spite of their well directed efforts the British surgeons noted 101 septic cases out of 170 gunshots of the femur in South Africa. Out of twenty-nine deaths, twenty-six or 89.6 per cent. died of sepsis.

Excision.—Excision of the femur for gunshot fracture never was a popular method of treatment and, like excision of the humerus, it is no longer advocated by military surgeons. It proved to be a very fatal procedure in our Civil War. Otis records 175 excisions of the femur for gunshot fracture. Ninety-one of these were done in the primary stage with a mortality of 76.4 per cent. Thirty-eight cases in the intermediate stage with a mortality of 81.2 per cent.; and eighteen in the secondary stage with a mortality of 16.6 per cent. All the cases for which primary excisions were once resorted to are now

amenable to treatment by conservation. The only possible excuse for exsecting part of a fragment now is found in cases where the jagged end of a bone is uncovered by periosteum. This should be rounded off with a rongeur, otherwise the fragments which still adhere should be replaced, as already recommended, as far as possible to their normal position, and the case treated conservatively.

Amputation.—At the same time that conservation is the rule of treatment for gunshot fracture under modern conditions, there are cases in which primary amputation is the only measure to be resorted to. It is absolutely indicated (1) when a limb has been entirely or partly torn away by a large projectile or shell fragment; (2) in comminuted fracture with great destruction of soft parts common to wounds from large shell fragments; or (3) in comminuted fractures attended with destruction of the femoral vessels should the patient live long enough to reach hospital care, and again (4) in comminuted fractures with destruction of soft parts complicated by destruction of the great sciatic nerve high up, all require amputation. In cases where there is doubt, the environments often decide in favor of amputation to the exclusion of conservation. The crowded condition of the field hospitals, and the lack of a sufficient force of trained assistants to properly safeguard the wounded against infection are conditions that are apt to compel amputation in military practice at times. Enforced transport is harmful to all kinds of fractures, it is prone to bring on or to aggravate existing infection and this is especially true of gunshots of the femur. Whenever possible these fractures should not be moved for a month or six weeks.

When the thigh is torn away by a large shell fragment, bleeding vessels should be tied, the skin and soft parts should be disinfected and dressed antiseptically pending the disappearance of shock, which is generally present in all such cases. When reaction has set in, part of the femur should be removed through a longitudinal incision on the outside of the thigh and the soft parts trimmed and cleansed, the vessels should be tied, and the end of the bone properly covered. This tentative method of dealing with cases when the thigh is torn away becomes more imperative as the site of the injury nears the upper end of the femur. If a better stump is desired later, it can be obtained by performing a new amputation.

We had 132 gunshot fractures of the femur in the Spanish-American War and the British Army in South Africa had 170 cases. If we place

the two groups together for comparison as to death rate after amputation we find the following:

AMPUTATION OF THIGH FOR GUNSHOTS IN THE SPANISH-AMERICAN AND BOER WARS

Position	No. cases	Died	Death rate
Upper third......	27	14	51.8
Middle third.....	21	9	46.6
Lower third......	11	3	27.2
Totals.......	59	26	42.5

Besides the cases given in the foregoing table the British had thirteen amputations at the hip for gunshot fracture of the femur with eight deaths, a mortality of 61.5 per cent. and six amputations of the thigh, the point of amputation "not specified," with three deaths, a mortality of 50 per cent. If we add these to the foregoing table we have a total of seventy-eight amputations for gunshot of the femur with thirty-seven deaths or a mortality of 47.4 per cent. There was a considerable number of the fractures due to shell wounds in South Africa and but two cases in the Spanish-American War so that by grouping the cases from the two wars we have the results as far as the character of the lesions is concerned nearer the condition which must obtain in the wars of the present.

The mortality after amputation of the thigh for gunshot fracture in the wars of to-day is higher than one would expect from the favorable results that attend other operative procedures under modern conditions. The mortality in the preantiseptic era was always very high. In the Crimean War out of 1666 amputations of the thigh there were 1532 deaths, a mortality of 91 per cent.; in our Civil War out of 6229 amputations of the femur, of which 2900 were performed for gunshots of the femur proper, there were 3310 deaths or a mortality of 53.8 per cent.; and of 9017 amputations of the thigh as a result of gunshot collected by Otis in the important wars, between 1689 and 1876, there were 7049 deaths, a mortality rate of 83.2 per cent. It is safe to state that the vast majority of fatal cases in the preantiseptic era died as a result of sepsis. The curse of the latter which pursued the older surgeons seems still to cling to the practice of military surgery. Thus Hickson states that of the 170 cases of fracture of the

femur in the Anglo-Boer War amputation was resorted to in forty-five cases with a death rate of 53.3 per cent., and that the indication for amputation was septic infection in all of the cases except three, which required amputation as a result of severe primary hemorrhage. Of the thirty-one amputations of the thigh in our records for the Spanish-American War the indication for operation as far as we are able to learn was septic infection in the large majority. These facts are touched upon, not with a view to criticize adversely the practice of the field surgeons, but to lay renewed stress upon the necessity for the exercise of the greatest care in the management of gunshots of the femur from the time of the first dressing. In cases which exhibit doubt as to the necessity for exploration, the decision should always be in favor of operation. Enlarging the wound of exit, removal of loose fragments, thorough irrigation of the foyer of fracture with a weak antiseptic solution and the establishment of good drainage, will keep sepsis in abeyance and check it ultimately, and when this is done the principal reason for amputation with its high mortality will have been set aside.

Gunshot Fractures of the Leg.—There were 9171 injuries of the bones of the leg in our Civil War, of which 183 are ascribed to shot contusions, while the remainder were shot fractures. The statistics of our war hospitals at that time show that about one-third of the fractures of the long bones are found in the leg, and that they form about 3 per cent. of war wounds by gunshot.

The tibia and fibula are harder than the long bones generally, and on account of their exposed position in the lower part of the leg the fractures in this location exhibit a high degree of comminution, amounting to explosive effects in a considerable proportion of the cases. The latter, though not specially dangerous to life, call for a large percentage of amputations.

Contusion of the bones of the leg was more frequent with the use of the lead bullets of the old armament. They are so far but seldom referred to in the wars of the present. Still, the exposed position of the tibia and fibula will render them liable to this form of lesion. Otis found that the internal surface of the tibia is more liable to this accident than the other surfaces of the bone. Out of 175 contusions treated by conservation he found the lesion located on the internal surface in 132. Contusion of the fibula is less serious than that of the tibia.

Treatment of Contusion.—The rule of treatment is the same as that laid down for contusion of bone from gunshot already referred

to, and this consists largely in employing means to prevent sepsis. Projectiles lodged adjacent to bone should be removed as soon as located, and the limb should be immobilized from the beginning. With the first evidence of inflammatory disturbance in the bone implicated, free incisions should be made down to, and including the periosteum, and when the history of the case calls for it, the compact substance of the bone should be trephined down to the medullary canal, and this mode of drainage should be repeated in the continuity of the bone at such points as may be deemed necessary. Good drainage and thorough irrigation with antiseptic solutions will usually arrest the bone lesion, and when they fail amputation is called for. Otis refers to 183 cases of gunshot contusions of the bones of the leg in our Civil War, of which 165 were treated by conservation with fifteen deaths; eight were amputated in the leg with four deaths; one amputation was done through the knee-joint with fatal result and nine suffered amputation in the thigh with six deaths. We have detailed the results in these cases of contusion to call special attention to the dangerous nature of such lesions. We have reason to believe that under our modern methods of wound treatment the sacrifice of life and limb mentioned can now be materially lessened.

Treatment of Gunshot Fractures of the Tibia and Fibula.—The treatment of gunshots of the diaphyses of the bones of the leg will be dealt with under (1) treatment by conservation, (2) excision, (3) primary amputation and (4) secondary amputation.

(1) **Treatment by Conservation.**—Out of 146 gunshot fractures of the bones of the leg treated by conservation in the Spanish-American War we had six deaths or a mortality of 4.1 per cent., while the mortality after amputation in fifteen cases was 13.3 per cent.

The British returns from the South African War give account of 137 cases as follows: Fracture of the tibia and fibula, 48; fracture of the tibia alone, 72; fracture of the fibula alone, 17. The great difficulty in treating gunshot fracture of the leg is the almost uniform presence of infection. The British returns which contain accurate records on this point show that thirty-eight cases out of forty-eight fractures of the tibia and fibula together were septic. Although the number of septic cases is not available in our records, we have reason to believe that the percentage of septic cases was high. The shoes, boots, leggings and clothing surrounding the legs of soldiers in campaign are necessarily soiled unduly with dirt from the surface of the earth, and a gunshot through the leather and fabrics mentioned contaminates

the wound with septic microbes which find lodgment on shreds of clothing, pieces of leather, particles of skin, etc., which are carried into the wound by the bullet. Wounds in war do not receive the prompt attention that is generally bestowed upon them in fixed hospitals. Men lie where they are shot for a long time unattended. In a great battle, it may be days before all the wounds are properly dressed. Delay in gunshot fractures, where infection is unavoidable as it is in wounds of the leg, means a rapid spread of the infection, and unless medical officers have the time and opportunity to grant the unremitting care and attention necessary to control the inflammatory conditions that already exist, there will be troublesome complications to combat later. A clean dressing and immobilization are the first indications in gunshot fractures of the leg. This is about all that can be done at a first-aid station. The dearth of water that generally obtains on the line has made this class of injuries hitherto difficult to deal with. We used to apply a clean dressing to a dirty field and trust the case to nature until a more favorable opportunity. Now we have in tincture of iodine or one of the iodine preparations already mentioned a valuable method of sterilizing the surface surrounding the wound, so that any additional infection from this source is preventable. At the earliest opportunity, those cases which require exploration should receive prompt attention. The wound of exit should be enlarged, and all loose fragments should be removed. Bleeding vessels should be tied, and when either the anterior or posterior tibial arteries are wounded the condition of its corresponding tibial nerve should be investigated, and when cut or lacerated it should be sutured. The bone splinters that remain attached to periosteum or soft parts should be put back in their normal position or as nearly so as possible; drainage should be employed; the wounds thoroughly irrigated with a weak antiseptic solution, dressed in the usual manner and the limb immobilized. A box splint or any of the methods generally used will answer at first; and later, nothing is better than a plaster-of-Paris splint. When the seat of fracture is near the knee-joint, the immobilizing apparatus should invariably include the latter.

The following case exhibits the excellent results attainable under modern conditions: Captain James H. McC., 1st U. S. Vol. Cavalry (Rough Riders), was shot at the battle of Guacimus during the advance on Santiago, June 25, by a Spanish Mauser bullet. The bullet entered posteriorly and to the tibial side of the left leg 5 1/2 inches above the internal malleolus. It smashed the tibia at this

point badly and fractured the fibula. There were three small wounds of exit on the anterior surface of the leg just below the level of the wound of entrance. The wound was at once dressed with a field dressing. At noon the next day the writer assisted in operating upon the case on the hospital ship Olivette. While the patient was under ether we found the area of fracture in the tibia marked by the presence of a number of small pieces of loose bone near the wounds of

Fig. 150.—Radiograms showing postero-anterior and side views in the case of Captain James H. McC.

exit. The Mauser bullet had separated from its jacket and a number of pieces of the core and envelope were also removed. The wound was thoroughly irrigated with a 1–2000 bichloride of mercury solution and then immobilized. In March, 1913—nearly fifteen years after the occurrence—the writer was able to secure a skiagram of Captain McC.'s leg. There is no deformity in the fibula, and but little deformity in the tibia. Particles of lead from the core of the bullet are still embedded in the tissues. There is 3/4-inch shortening and some limitation of motion in the ankle as a result of injury to the tendo achilles (Fig. 150).

Without the prompt and radical treatment that was practised in this case, there would have been long-continued inflammation of the surrounding tissues, and all the bone lesions that are common to such injuries.

Fig. 151.

Fig. 152.

Fig. 151.—Photograph in case of Pvt. D. C. S., Co. "E," 20th Mass. Lower-halves bones leg six months after injury. Tibia fractured by musket ball. Suppuration continued till amputation of limb six months later. Civil War specimen. No. 861 A. M. M.

Fig. 152.—Photograph in case of W. A., Pvt. Co. "L," 8th U. S. Inf. Gun-shot fracture received in action in Philippines, Dec., 1906. Nature of weapon unknown. Amputation Oct., 1908. Photograph represents femur after amputation, it shows the later bone lesions that result from failure to promptly remove loose fragments from a comminuted fracture, a common condition in Civil War days. Army Med. School collection. From X-ray Laboratory, Lettermann Genl. Hospital.

We have selected two specimens from the Army Medical Museum to illustrate the ulterior effects of the old-time practice in bone lesions

of gunshot wounds when expectancy and conservation were restricted largely to the efforts of nature (Figs. 151, 152 and 153).

(2) **Excision of the bones** of the leg in their continuity is not a safe surgical precedure. It is sometimes done in a case showing great loss of substance in the tibia by resecting the fibula to correspond to the length of the injured tibia. In such a case the ends of the bones are to be wired. The success of such an operation depends on rigid sepsis, a condition that can seldom be assured in field practice.

FIG. 153.—Skiagram from case of W. A. Leech, Co. "I," 3rd Wis. Vol. Inf., shot during Civil War 1861–65. Missile not stated. Recovery took place after much suppuration. Skiagram taken in 1911. A. M. School collection.

(3) **Primary amputation** of the leg is only practised now for extreme destruction of the soft parts with fracture, or when a limb has been carried away, lesions that are common to impact from large projectiles or their fragments. Primary amputation as a result of gunshot fracture from the projectiles of hand weapons will be seldom required. A comminuted fracture of both bones with destruction of both tibial arteries would constitute a cause for amputation, but such an injury is seldom seen from the effects of hand weapons except in the case of rifle shots delivered at close range exhibiting explosive effects, or as a result of shot from a shot gun delivered at contact or thereabouts. Modern methods of treatment have materially modified military practice concerning amputation of the leg. After the battle of Waterloo, Thompson recommended amputation (1) when a ball had fractured both bones of the leg; (2) for gunshot fracture near the knee or ankle with joint involvement; (3) when a ball was deeply lodged in the tibia; and (4) for fracture of the tibia with injury to the blood supply. In our Civil War the mortality for 5452 amputations of the leg was 32.9 per cent., while the

mortality for 3938 cases treated without operative interference was 13.8 per cent.

Improvement as a result of conservative treatment had become evident even in the days of the Civil War, since Otis shows in a tabular statement, in which there appears 2989 cases from the time of the Thirty Years' War to and including the Russo-Turkish War of 1876–77, which has a mortality rate of 18.5 per cent. or 4.7 per cent. greater than the results of our Civil War. But the remote and ulterior effects of conservative treatment as practised at that time should not be forgotten. As late as 1881 the Reports of the Pension Examiners "are replete with accounts of extensive caries and necrosis with continued discharge, enlargement of the limb, irritable ulcers, overlapping with projection of fractured ends, outward or inward curvature, ankylosis of the knee or ankle or both, contraction of toes, outward turning of foot giving the ankle the appearance of being dislocated, extensive and adherent cicatrices, atrophy and weakness, and inability to sustain the weight of the body" (Otis).

(4) **Secondary Amputation.**—Sepsis and the complications to which it leads are the causes of secondary amputation. Secondary amputations as compared to primary amputations constitute the bulk of the amputations in recent wars. In the days of the Civil War the term intermediary amputation was employed and it had reference to amputations performed soon after the onset of acute inflammatory manifestations. Under modern methods of treatment we combat cases showing active indications of sepsis and defer amputation if necessary to a time when efforts at conservation have entirely failed, so that our secondary cases appear proportionally larger in number than those in the American Civil War. The following are the number of amputations of the leg at different periods and the mortality rate recorded by Otis:

	Amputations	No. of recoveries	No. of deaths	Per cent.
Primary	3392	2307	1032	30.9
Intermediate	1046	682	364	34.75
Secondary	444	327	117	26.3
Totals	4882	3316	1513	30.98

If we compare the total number of amputations of the leg and their death rate from the Government returns for the Spanish-American and Boer Wars we find as follows:

War	Cases operated on	Died	Death rate
Spanish-American..	15	2	13.3 per cent.
Anglo-Boer..........	32	8	25.2 per cent.
Totals........	47	10	21.2 per cent

The records show that nearly every one of the amputations in the last two wars was done as a result of sepsis. In other words they represent the class that would have figured under intermediate and secondary amputations in the Civil War. If we add these two together in Otis' table we find a total of 1490 intermediary and secondary amputations with a total of 481 deaths or a mortality rate of 32.2 per cent. as compared to 21 per cent. for the Spanish-American and Anglo-Boer Wars. This gives 11.2 per cent. in favor of modern armament and antiseptic methods of treatment. The mortality after amputations of the leg in the Spanish-American and Anglo-Boer wars is entirely too high. Our object in making the foregoing comparisons is to call renewed attention to the necessity of exercising greater care in battling against sepsis in war. Gunshot fractures of the long bones should be among the very first to receive the attention of surgeons and this should be carried out on the lines laid down under conservation in the large majority of the cases.

The kind of amputation to be performed will depend upon the lesion to the soft parts. Speaking generally, as much of the limb should be retained as the injury will permit. When amputation is required for osteomyelitis the point of election is through the knee-joint, or the lower third of the femur.

In dealing with the results of gunshot fractures in this chapter as far as they relate to the wars of the present, we have confined ourselves largely to the Government reports of the Spanish-American and Boer Wars. Although the number of cases is not large, we believe that when the Government reports of larger wars like the Russo-Japanese and Turko-Balkan Wars are available the results in the

United States and English reports will very nearly represent the conditions in more recent wars. We have never laid much stress upon the reports of isolated observers from any of the later wars, because the general results of war wounds can only be estimated after due consideration of the sum total of wounds received, and for some time after cessation of hostilities.

GUNSHOT WOUNDS OF THE FOOT

In our Civil War Otis records 5832 gunshot fractures of the foot and 11,369 fractures of the bones of the hand. The bones of the foot suffered one-half as often as those of the hand. It is safe to predict that this proportion will be much less hereafter. While fighting under cover in modern tactics, the foot is one of the least exposed parts of the body, while the hand is exposed as much now as formerly.

Infection is prone to occur in gunshot wounds of the foot in the military service especially. The opportunity to dress the cases in active campaign is often delayed so that dirt from the shoes, or boots, and stockings driven in by the bullet has infected the wound before the application of a suitable dressing has been made. Once inflammation has gained access to the wound, it is difficult successfully to combat its spread because of the intimate relation between the bones and joints of the tarsus and metatarsus. Fractured bones, when exposed to inflammation in such inaccessible regions, are apt to undergo necrosis and exfoliation. The inflammatory process is often prolonged in spite of the active measures of treatment that are instituted. The effects in the end are toward ankylosis of the ankle and adjacent joints, loss of the arch, and utility of the foot for walking.

The mortality of gunshot fractures of the foot in our Civil War, largely as a result of sepsis, aggregated 8.3 per cent.; and 7.8 per cent. in the Franco-German War of 1870 and '71.

Out of 158 cases of gunshot fractures of the metatarsus and toes reported by the Surgeon-General, U. S. Army, for the years 1898 to 1900 inclusive, there were but three deaths, and two of these are ascribed to other causes. Reduced-caliber bullets were responsible for fifty of the cases, and two to shell fragments. One hundred and eighteen were restored to duty; sixteen were discharged for disability and the others were discharged by order, expiration of term of service, etc.

In spite of the efficiency of the modern treatment of gunshot

wounds, Stevenson reports fourteen septic cases out of thirty-two gunshots of the tarsal and metatarsal bones in the Anglo-Boer War. There were no deaths, twenty-four were inflicted by rifle bullets, seven by shell. Twelve cases exhibited perforation, there was

Fig. 154. Fig. 155.

Fig. 154.—Shows the result of a transverse shot through metatarsal bones of foot in a soldier at Santiago by a Mauser bullet. Radiogram was taken 22 months after injury. Callus formations were painful in sole of foot on walking.

Fig. 155.—Shows foot after we had amputated two toes and part of corresponding metatarsal bones, Fig. 154. Radiogram taken 25 months after injury. Army Medical School collection. U. S. Soldiers Home X-ray Laboratory. Dr. A. B. Herrick, X-rayist.

grooving in five, and comminution in thirteen. The condition of the foot was good in five, and bad in six cases. Primary amputation was performed in the shell cases, and there were two secondary amputations in the leg.

Treatment.—Conservation is to be employed in the large majority of gunshots of the foot. Primary amputation is indicated in nearly all cases resulting from shell fragments. The mode of amputation will depend upon the amount of destruction of bone and soft parts The classical operations of Hey, Chopart, or Syme are usually employed.

Fig. 156.—The following case is of special interest to recruiting officers. Pvt. Raymond H. R. Co. "H" 13th Inf. A .22 cal. rifle bullet lodged in metatarsal bone great toe, accidentally inflicted; detected by X-ray two years after enlistment. Was admitted to sick report for "arthritis subacute, metatarso-phalangeal joint great toe." Army Medical School collection. X-ray Laboratory, Fort Leavenworth, Kansas.

Secondary excision may become necessary when conservation fails, in which case the removal of the foyer of suppuration will have to be practised. This may include any part of the foot. Painful callus is another cause for partial excision. Transverse shots across the foot by modern rifle bullets are attended with many displaced fragments and resulting callus, for the relief of which operative interference at times becomes necessary (Figs. 154, 155).

Hemorrhage from the larger vessels traversing the sole of the foot is not an infrequent complication. Bleeding from such a source is best controlled by tying both ends of the injured vessel. Pressure is uncertain except for hemorrhage from the smaller vessels, and ligation of the anterior and posterior tibials is apt to end in gangrene.

The greatest care should be employed in cleansing the wound and the surface adjacent to it before applying the first dressing. Exploration should be avoided except for the removal of missiles or loose bone fragments. After the application of a sterile dressing immobilization should be applied.

CHAPTER XIII

Medico-legal Phases of Gunshot Wounds

The medico-legal phases of gunshot wounds require a consideration of certain points, with definite answers, as far as these are obtainable by evidence at the time of occurrence, and such evidence as may be adduced by a knowledge of firearms, projectiles, explosives, etc. The behavior of the last two on tissues and clothing at the time of discharge frequently affords evidence of the greatest value. The effects of projectiles and explosives on the body involve many problems that are submitted to the medical witness for solution which may be discussed under the following headings:

1. Diagnosis of a Wound Caused by Firearms.
2. At What Distance was the Firearm Discharged?
3. When was the Wound Inflicted, Before or After Death?
4. Is the Wound Dangerous to Life?
5. The Practitioner's Liability in Case of Infection.
6. How was the Wound Inflicted?
7. Was it Accident, Suicide or Homicide?
8. Identity of the Individual by the Flash of the Firearm.
9. Self-inflicted Non-fatal Wounds.
10. At What Time was the Firearm Discharged?
11. Was the Projectile Jacketed or not?

1. **Diagnosis of a Wound Caused by Firearms.**—The appearance of a gunshot wound is at times atypical and doubt arises as to whether the injury was the result of gunshot. Doubt is reasonable only when superficial bruise or abrasion is found. A gunshot wound is marked by a wound of entrance and most generally by a wound of exit.

Wound of Entrance.—The skin wound of entrance corresponds to the diameter of the projectile inflicting it. At times the aperture of entrance appears smaller than the diameter of the projectile, but the difference is only apparent since the wound invariably admits a projectile of like caliber to the one which has caused it. The smaller appearance is due to shrinking from the elasticity of the skin. Wounds inflicted in skin overlying bone or resistant aponeurosis will show a

wound of entrance exceeding the size of the bullet. The edges of the wound may be scorched or not, depending on the proximity of the muzzle at the time of discharge and to the kind of powder used. Black powder which liberates its gases by ignition causes burning and tattooing with proximal shots; the nitro-cellulose powders and detonators do not cause burning, and tattooing is less marked. The lead bullets which were formerly lubricated left a dark coating about the edges of the entrance wound in the skin which simulated the appearance of burning, but close inspection in such cases revealed the true nature of the discoloration. The edges of the entrance wound are more or less inverted, lacerated, bruised and surrounded at times by ecchymosis. The wound of entrance contains bony sand in some gunshot wounds from the reduced-caliber rifle when fracture of a resistant bone has taken place at the proximal ranges. The wound is rounded when the piece is held at some distance. When the muzzle is held at contact the skin is torn and lacerated. Bleeding is slight unless a vessel near the surface is injured, but bleeding is more often seen at the wound of exit. Direct impact causes a round wound of extrance, while tangential shots show oval skin apertures. A wound of entrance in skin overlying loose areolar tissue like the scrotum may appear much smaller than the projectile on account of the extreme elasticity of the skin in this region. Bullets from the high-power reduced-caliber rifles often show a mere slit in skin, which is wrinkled like that of the scrotum, neck or knee.

Wound of Exit.—The exit aperture never exhibits tattooing, burning or other disfigurement from the powder charge. It is usually larger than the wound of entrance and in cases of bone lesion it may exceed the size of the projectile many times. It is more irregular than the wound of entrance. The edges of the wound are everted, and subcutaneous fat may protrude from it. In cases of gunshot fracture at proximal ranges by the reduced-caliber rifle, the wound of exit may be multiple from pieces of the bullet or particles of bone having been driven forth with the bullet as secondary projectiles. For reasons not easily explained there are cases in which the wounds of entrance and exit are so nearly alike that it is difficult to distinguish the one from the other. The wounds of entrance and exit of a jacketed bullet at proximal ranges are very much alike when soft parts alone have been traversed. Low-velocity projectiles composed of lead are apt to be deflected and many instances are given of bullets following the contour of the body. The high-velocity military and sporting rifles

of the present day shoot projectiles that travel in a straight line, and it is safe to assert that the channel of a bullet from these weapons is marked by a straight line drawn between the entrance and exit wounds when the parts have been placed in the position which they occupied when hit.

Multiple wounds are common in shotgun injuries, and they give valuable evidence of direction when but one shot has been fired. As a result of superior velocity and penetration, multiple wounds from one shot are common with the present-day military and sporting rifles of reduced caliber. A man entered the hospital at Siboney, in the Santiago campaign, with six wounds inflicted by one Mauser bullet, implicating the right shoulder and both breasts. There were a number of instances in which wounds of the body were associated with wounds of the arm or forearm, or both, the latter being in a state of flexion at the time of injury. Capt. . . . . 7t Infantry, received four wounds of the face followed by no disfigurement. The projectile, a Mauser, entered the right cheek below the outer canthus, emerged on the nasal side. It next entered the right side of the nose and emerged on the opposite side. Wounds of entrance and exit in the upper thighs were several times complicated by wounds of the scrotum or penis by the same bullet.

2. **At What Distance was the Firearm Discharged?**—The distance between the muzzle of the weapon and the point of impact is one of the most frequent questions propounded to the medical witness in courts of law and it is not always an easy question to answer. The appearance of powder grains buried in the skin and the way in which they may have penetrated certain thicknesses of clothing will sometimes indicate the approximate distance at which a pistol or other weapon was held when fired. Burning of the clothing, scorching of the skin, or singeing of the hair, which is apt to occur with the use of the old black powder, furnished invariable evidence of a shot at close range and it often indicates the manner in which the weapon was held when fired. Each weapon with a definite charge of the propellant has a distance limit where deposits of powder grains will make an impression upon the surface. The same may be said of the "powder brand" first described by Dr. B. F. N. Fish of Boston.[1] In experiments which he made on blotting paper with pistols he describes the powder brand as follows: "I noticed, in addition to the smutting of the paper by smoke and to the marks of the burned and unburned grains

[1] Dr. B. F. N. Fish, Boston Med. and Surg. Journal, Oct. 2, 1884.

of powder distributed around the bullet hole, one spot blacker and more burned than the rest. I found this was caused by the flame of the gases of the burning powder, and by the residue or ash of the burned powder striking and resting in this place. I also noticed that this burned and blackened spot held a most constant position, directly above, or above and a little to one side of the bullet hole." He also found that the powder brand about the bullet hole invariably occurred on the hammer side of the weapon. That is, if the pistol or revolver was held hammer to the left, the powder brand occurred on the left of the orifice made by the bullet. When the weapon was held with the hammer to the right, the brand was noticed to the right of the bullet hole. When the weapon was held with the hammer up or down, the brand was located likewise above or below the bullet hole. The explanation of the position of the powder brand is as follows: As the weapon, a pistol or revolver, is held in the hand the latter forms the point of support for the recoil. The point of support is below the line of application of the force generated by the ignited powder and on discharge the force tends to make the weapon revolve about the point of support. The projectile is first discharged and as the weapon revolves upward the gases behind the ball follow the new direction assumed by the barrel, and the products of combustion are thus delivered on the target above the bullet hole, to one side, or below according to the way in which the hammer is held. If the weapon is held stationary in a vice when fired, the recoil does not affect the direction of the barrel and the brand and tattooing are equally distributed about the bullet hole. When held normally in the hand the distance of the brand from the bullet hole is greater as the distance between the weapon and target increases: the angle made by the barrel in its alignment before and after the recoil is the same, but the line on the target which subtends this angle will naturally increase with the distance from the point of discharge.

The appearance of the powder brand has frequently figured in the courts.[1] When present, it has afforded strong presumptive evidence of suicide or homicide.

The powder brand as described is better marked with the use of the old black powder in pistols and revolvers. We have found that the greater number of powder marks, independently of the brand, was invariably on the hammer side of the weapon. This was the case with

[1] Text-book of Legal Medicine, etc., Peterson and Haines, article on Gunshot Wounds by Dr. J. N. Hall, W. B. Saunders Co., Phil., 1903.

all the specimens tested with the exception of the Peyton powder when shot out of the military rifle. With this the majority of the powder grains appeared below the bullet hole when the rifle was held in the regular way. It is possible that other brands of powder will act likewise, hence the necessity of conducting tests in any given case.

Witnesses in courts of law often need to know the behavior of the different explosives relating to the degree of powder burn or tattoo as modified by the distance of the object, the size of bore and length of barrel, the amount and standard of powder, etc. The exhaustive experiments which we made in 1905 may be of assistance to future experimenters or to those who have occasion to seek information as witnesses. In these experiments we tested the effects of the more common rifles and revolvers used in this country, from which we fired nearly all the brands of black and smokeless powders in the market at that time.[1] Not infrequently the weapon is pressed against the surface and held tightly by the suicide so that the gases and the unconsumed particles from the propellant are driven into the wound and the skin about the wound of entrance will give no evidence of either brand or tattoo. Unless the wound is carefully examined the proximity of the weapon at the time may be overlooked. The wound in such a case would have the appearance of one having been inflicted at some distance. In the case of Normal Harris, which was noted by Dr. C. S. White of Washington, the suicide held the .38-caliber pistol against the scalp behind the right ear and fired. There was no scorching of hair or skin and no evidence of marks like tattooing left by the powder on the scalp. The suicide was found dead in an alley with a bullet hole in his head and, to add to the complication in the case, the weapon with which he had inflicted the wound had been taken by someone who happened to be passing by. A careful examination of the wound proper revealed particles of the propellant and gave positive evidence of a shot delivered at close contact.

The distance from the weapon can sometimes be determined approximately by the amount of penetration of the projectile. As a rule the penetration is in proportion to the velocity. Close shots penetrate farther because the bullets have a maximum velocity. Formerly shots from pistols and revolvers seldom emerged from the body when they happened to collide with resistant bones. Perfection

[1] Experiments Illustrating the Degree of Powder Burn, etc., Journal Assn. Mil. Surgeons, Vol. V, 1895, p. 212.

of the more modern types of revolvers and the automatic pistols which employ steel-jacketed bullets have come into use with an initial velocity as high as 1400 f.s., and the penetration of projectiles for these weapons has been correspondingly increased.

A lead bullet possessed with maximum velocity will at times fail to penetrate as far as it does when animated by a lower velocity. Experimenters often notice, for instance, that a .38-caliber Colt's revolver bullet will perforate the skull of a cadaver at 25 feet, when it will fail to do so at contact or a foot or two away. The explanation given is this: a lead bullet traveling at a maximum velocity makes such a sudden and violent impact that bone particles have not time to separate or give way to enable the ball to pass. The momentary resistance is such that the bullet flattens, hence the deformation which adds to the sectional area of the bullet, and to this deformation we ascribe the loss in penetration. This point came up recently in the case of a young officer of one of our services when the government sought to show that the officer came to his death by suicide by shooting when he lay on the ground in a struggle with other officers who were endeavoring to restrain him. The muzzle of a .38-caliber new service Colt's revolver was held against the right side of the head and fired. The ball entered the skull and was lodged in the brain substance on the opposite side more or less deformed. The prosecution maintained that the pistol discharged at such close range should have sent the ball through the head and that in all probability the pistol was discharged at some distance by someone else. There were eye witnesses to the occurrence, and other evidence to confirm the charge of suicide. The experts consulted in the case held to the opinion that the failure of the ball to make a complete perforation at such a proximal range was due to loss of penetration by deformation of the bullet at the time of impact. See also case of Sergt. V., Figs. 107 and 108, page 177.

Wounds from Shotguns.—The penetration of pellets from shotguns varies naturally with the amount and kind of charge, the distance of the weapon and the age of the explosives. In cases where the court desires information on the degree of penetration of lead pellets or projectiles fired from any weapon, experiments to simulate the conditions at the time of occurrence in a given case should be resorted to, either on cadavers or other materials.

Wads and wadding from shotguns and pistols depending on the compact nature of the materials from which they are made have caused fatal results at close quarters and the charge of powder alone

from any weapon is at times sufficient to cause death when discharged nearby.

Projectiles from shotguns may be fine or coarse shot, slugs, pieces of metal of any kind, pebbles or a ball. Unless the latter is used the effectiveness of the weapon hardly exceeds 100 yards, although instances of death beyond this distance from stray pellets are recorded. The caliber of shotguns varies approximately between .424 inch to 1.052 inches. The charge of shot makes a close target in accordance with the degree of "choke." When the choke is absent the tendency to spread is markedly shown. The charge has a single point of entrance at from 1 to 2 feet depending upon the kind of weapon and the manner of loading. The wound of entrance when the charge takes effect en masse is never so regular as it appears in the case of a bullet. Separate shot holes appear as the distance increases. The pellets diverge on entering, as a rule, and this is especially true if a bone is hit. An X-ray of the surrounding parts will generally indicate the amount of spreading. The paper-shot shell has been known to separate from its metallic head and deliver a wound in a single load as far as 200 yards.

Evidence of Proximity Afforded by Clothing.—Perforation of the clothing from a projectile takes place very much in the way that the skin is perforated. The hole entering the dress is round if the velocity of the bullet is high. A lower-velocity bullet pushes the clothing forward in the shape of a cone, the apex of which is perforated in the form of a slit or triangular tear. After the perforation has taken place the clothing assumes its original position or part of it may hang in the wound. The bullet hole is small in proportion to the elasticity of the stuff penetrated. Clothing that is stretched over the body at the time of perforation shows a hole approaching the size of the bullet. Powder burn or stain may occur from close shots. The zone of burning is round or oval as the shot is delivered perpendicularly or at a tangent to the cloth. Unburned powder grains can be picked out of the cloth and with the aid of a magnifying-glass Doctor J. N. Hall, of Denver, Colorado, was able to prove in a recent court case that the shooting took place 2 or 3 feet from the muzzle by demonstrating isolated patches of burned fabric due to ignited grains when the distance had been too great to cause burning by the flame.

3. **When was the Wound Inflicted, Before or After Death?**—This question is important, and it is often asked to arrive at the length of time the wounded person may have survived after receiving a mortal

wound. This can only be arrived at by the appearance of inflammation in life, which does not set in with anything like distinguishing features until the lapse of ten to twelve hours in tissues generally, although we know that plastic lymph is thrown out in a wound of the peritoneum in about three hours. The question of the wound having been inflicted before or after death is not easy to answer unless the missile has injured a vessel with resulting hemorrhage and the formation of coagula. Gunshot injury in dead tissue is not followed by hemorrhage unless the projectile happens to wound a large blood-vessel and preferably a vein. Evidence of the movements the wounded may have made after receiving the injury will sometimes throw light on the subject.

In a case where several wounds may be found on a dead body it is sometimes pertinent to know which of the wounds caused death. The question can only be answered on general principles, taking into consideration the nature of the wound, the parts injured, the amount of injury to vital organs, etc. In a street encounter in one of our Southern cities recently a man of prominence was shot with an automatic pistol several times in quick succession through the body. Eye witnesses saw the wounded drop lifeless to the ground very suddenly during the scuffle that was going on. The post-mortem revealed several wounds capable of causing death. In one of these the ball severed the medulla oblongata. The medical witnesses testified that this wound had caused immediate death, and that it was received when the wounded was noticed to drop lifeless to the ground.

4. **Is the Wound Dangerous to Life?**—The danger to life is dependent upon the anatomical regions traversed, the local and general resistance, and the complications that are apt to set in. The danger in gunshot wounds has been lessened very much in recent years because of the change in firearms and in the projectiles they employ, and also because of the great advances in wound treatment. This beneficence has come largely from the reduction of the caliber and weight of the bullet but more especially from encasing the projectile in a steel jacket. The enveloped type of bullets does not disintegrate as the lead bullets did, their hard exterior prevents deformations that were once common and which added to the gravity of wounds. The small frontage of the rifle bullets ranging from .256 to .30 calibers adds to the humane features of the injuries in the soft parts, the epiphyseal ends of bones, the lungs and liver. Gunshot wounds of the abdomen in war that were uniformly fatal with the

old armament have given under modern conditions a hope of recovery in 25 per cent. of the cases without operation in wounds inflicted by the ogival-headed reduced-caliber bullet. But the recent change in the shape of the reduced-caliber military rifle bullet from an ogival head to a pointed bullet has again added very much to the fatality of all body wounds and abdominal wounds especially. This bullet, as already stated when discussing the characteristic features of gunshot wounds in Chapter II, has no stability. It turns on encountering the least resistance and when it does so while traveling with a rapid momentum its rending effects are terrific. The Turks used this bullet in the recent Turko-Balkan War with deadly effect; but few abdominal wounds lived to reach hospital care. The deadly slashing effect of this bullet has made it popular with sportsmen and it will no doubt be very much used in the hunt for large game.

Gunshot wounds of the abdomen in civil practice by the projectiles of pistols and revolvers, once so fatal, now give about 50 per cent. of recoveries under modern methods of treatment. When the wound is inflicted by the smaller calibers the death rate is much less.

Notwithstanding the beneficence which has resulted from the change in firearms and modern treatment, a perforating gunshot wound of the abdomen from any weapon should at all times be considered dangerous to life. The same may be said of gunshot wounds of the lungs. It may be stated as a broad principle that gunshot wounds are dangerous to life in proportion to the amount of tissue involvement. This is also true of wounds from weapons that appear to be attended with little danger like toy-pistol wounds. Wounds of this class have been described under toy-pistol tetanus and they owe their dangerous nature to the liability to infection from virulent microorganisms like the bacillus of tetanus in wounds that are marked by the presence of laceration and hæmatoma.

Gunshot wounds as a class are more or less contused and lacerated, and because of this fact their gravity never can be overlooked. The surgeon will have to form his estimate of the amount of danger in a given case bv his knowledge of regional anatomy and the importance that the tissues traversed may bear to life, directly or indirectly. The subject of wound infection plays a great rôle in danger to life. To appreciate this properly anyone who expects to testify in a given case should read carefully the chapter on Infection of Gunshot Wounds.

5. **The Practitioner's Liability in Case of Infection.**—The knowledge of antisepsis and the value of cleanliness are becoming so well

known to the laity that criminal negligence with sepsis resulting has already figured in the courts. Incidentally the subject brings up the medico-legal phase of septic bullets. There are two aspects of the practitioner's liability; he may be prosecuted criminally for negligence producing death, or he may be asked civilly to respond in damages by the party injured or by his heirs. For our purpose, however, the rules of evidence and the burden of proof may be treated as substantially the same. Speaking thus with approximate accuracy, if the plaintiff or the prosecution establishes (1) the existence of blood poisoning; (2) surgical uncleanliness i ı the use of the instruments or dressings; (3) failure on the part of the operator to render his hands or those of his assistants an(the field of operation aseptic in the ordinary way, a prima facie case is made against the surgeon which he must overcome. Such culpable negligence in the light of our present knowledge is considered unpardonable and yet in the case of a gunshot wound it would be difficult to say that sepsis had resulted from neglect alone or that a deadly poison like that of tetanus had resulted from said neglect and not as a result of a bullet infected with tetanus spores. Ordinarily the plaintiff might avail himself of evidence that (1) the patient's clothing, pierced by a bullet, was old and dirty, and hence probably not aseptic, and (2) that the skin at the wound of entrance and exit bore specific germs. Furthermore two additional lines of defence are open to him, viz., (1) the bullet itself might have been septic when fired, and (2) by ricochet, or otherwise while in transit, it might have become septic—two conditions either of which is well within the bounds of possibility. We have shown already by numerous experiments on animals shot into with septic bullets from many different kinds of weapons, and at ranges up to 500 yards with the military rifle, that a septic bullet is not rendered sterile by the act of firing, and that it can become infected in ricochet.[1]

6. **How Was the Wound Inflicted?**—This question refers to the position of the individual when shot. (a) Was he standing or lying down? (b) Was he running from his assailant or advancing? (c) In what direction was the weapon pointed when fired? (d) Was it fired from the shoulder or hand?

The above queries can all be established by eye witnesses. In the absence of such testimony we have to depend on such evidence as

[1] Are Projectiles fron Portable Hand Weapons Sterilized by the Act of Firing? Can a Septic Bullet Infect a Gunshot Wound? By Louis A. LaGarde, U. S. A. Proceedings Pan-American Congress, Vol. I, 1893.

may be afforded by the distinction of the wound of entrance from the wound of exit. In those cases where the distinction is well established the position of the victim when shot will be apparent. It will show whether the wound was received when facing the muzzle or whether his side or back was nearest the weapon. The track of the bullet from the point of entrance to the point of exit or lodgment is usually a straight line. When it is, we here have evidence to show how the weapon was pointed when fired. When a line between the two wounds or the wound of entrance to the point of lodgment is curved from a deflected bullet the value of the evidence bearing on the way in which the gun was pointed is doubtful. In former times such cases were frequent. The velocity of the projectiles was lower and they were easily deflected from their course before and after striking the body. Many cases are cited in the literature of gunshot wounds where bullets after entering the skin described a circuitous course through the subcutaneous tissues half-way around the body. In such cases the wounds of entrance and exit indicated a direct course when in reality, as determined by autopsy or otherwise, the ball had been deflected.

7. **Was it Accident, Suicide or Homicide?**—This question often comes up in cases of death from gunshot injury. An attempt at suicide shows a wound directed against a vital part, as a rule; the wound is not located on the back part of the body. A suicide often selects the inside of the mouth to reach the vital part of the brain, a location that could not be selected by a murderer, except on helpless individuals. In 368 suicides by firearms in France 297 were from wounds in the head; of these 234 were fired into the mouth, only seventy-one were from wounds inflicted on the chest or abdomen (Reese). The other favorite location selected is the temple and the right temple is chosen in the vast majority of the cases. Suicidal shots, as a rule, are delivered at close range, they generally show powder marks, the penetration and distribution of which should be carefully studied to ascertain the distance from the muzzle and the way in which the weapon was held. Here we refer to the powder brand and other evidence from the explosive which has figured so often in the courts and which we have already explained at length. With reference to the value of powder brand in cases of suicide, if one will take an unloaded revolver or pistol in his right or left hand and go through the execution which a suicide must follow to shoot himself he will at once learn the limited amount of motion that one commands in

directing the hammer to the right or left. The limit of movement when aiming at a target corresponds to the amount of pronation and supination of the wrist, and the area occupied by the different powder brands on blotting paper is about equal to a semicircle. A powder brand outside this semicirlce should favor the theory of homicide.

In an attempt at suicide there is usually evidence of design which is not shown in cases of accident. In the matter of design suicides have used strange weapons. Many unusual devices which bear evidence of the expenditure of time and thought have been employed. Aside from the ordinary weapons like pistols, rifles, and shotguns, they have been known to extemporize fowling-pieces out of iron piping, large hollow keys, toy cannons and bottles charged with explosives and sand, or gravel, nails, pieces of lead; and liquids like water, petroleum and rum have been used to take the place of ordinary projectiles. In summing up the evidence in a given case, one should not lose sight of the fact that design can be planned by a murderer in an effort to conceal crime. The shotgun or rifle is not so often employed by suicides, but when used there is usually evidence of design. In the case of a prominent jurist personally known to the writer a shotgun was used. A string about 2 feet long was tied by its middle to one of the triggers. A loop to admit the big toe was provided in each end of the string. He then sat on the edge of his bed and placing the muzzle of the weapon in his mouth, the gun was discharged by pressing the toes, which had been previously placed in the loops, toward the floor.

The question of suicidal or self-inflicted accidental wounds often figure in the courts with a bearing on insurance. Wounds from both causes will have the characters of near wounds. When the body or premises have not been disturbed, the relative position of the body and weapon will give evidence of the presence or absence of design in the majority of cases.

When the weapon is still firmly grasped in the hand it is proof positive that the wound was self-inflicted, but it affords no bearing on whether the wound was suicidal or accidental. The facts in such a case must come from other evidence.

When a wound is inflicted by accident on a second person, it is difficult without direct evidence to say whether it was accidental or homicidal. In such cases the lesion with reference to wound of entrance and exit, and the direction of the channel made by the ball

should be carefully compared with the statement of the person who did the shooting.

With old firearms, when loading was done by hand, wadding from paper and other material found in a wound has often served to establish the guilt of the offender. Thus, hand-writing on paper or print from paper wadding, has been found in some cases to have been torn from remaining particles in the possession of the person who had committed the crime. Evidence from such a source is rare now because nearly all ammunition is loaded by machinery. Still the projectile, wadding if any, and even particles of the explosive should be carefully preserved and turned over to competent authority for future study.

Chemical analysis of bullets was resorted to formerly to determine guilt or innocence. Lead bullets are now hardened with antimony and small shot contains arsenic. Old fashioned missiles of this class were composed entirely of lead. Lead slugs with neither antimony nor arsenic are occasionally used in shotguns. Thus in a case cited a number of deformed shot approaching the appearance of slugs were removed from a dead body. They contained arsenic, but slugs found in the prisoner's possession were arsenic-free.

Since the weight of the bullet at times enters into a case, it is always well to take the weight of all missiles extracted for future comparison.

8. **Identity of the Individual by the Flash of the Firearm.**—With the use of black gun powder there is ignition and the flash from shotguns, revolvers and pistols containing a sufficient charge will illumine the vicinity of the shooting in a dark room enough to identify the features of an individual as far as 5 meters when the observer is placed laterally to the one doing the shooting; and when viewed while facing the one shooting, the latter can be recognized as far as 10 meters.[1] The test is different with the so-called smokeless powders. With them there is no flash at the time of discharge because there is no ignition or fire. Experiments with black powder and the various brands of smokeless powder when fired into blotting paper will convince anyone of the truth of this statement. We have shot rifles, pistols and revolvers loaded with smokeless powder in a basement when the space was absolutely dark, with negative results in all instances.

9. **Self-inflicted Non-fatal Wounds.**—Self-inflicted wounds are at times made to avoid military service, to elicit money or charity, or to impute murder. Again a man making a futile attempt at

[1] Dr. Romary, Arch. D'Anth. Crim., 1908.

suicide will often endeavor to conceal his act, and ascribe the wound to the hand of an assassin. Examination of such wounds will show that with the exception of attempted suicide they will not be directed against vital parts. The skin will show laceration, ecchymosis, smut, burn or tattoo from gun powder. Marks of the powder may be on the hand holding the weapon, as so often happens in self-inflicted wounds. The powder brand when present will indicate how the weapon was held with reference to the direction of the hammer.

10. **At What Time Was the Firearm Discharged?**—This resolves itself into a very important question in many cases because its solution may serve to identify the weapon. If black powder was used K_2S will be found in the barrel shortly after discharge. Later oxidation produces K_2SO_4. Experiments under the condition of moisture and temperature prevailing at the time of discharge should give the time approximately. The author is not acquainted with any method which will fix the time if smokeless powder has been used.

11. **Was the Projectile Jacketed or Not?**—The effects of armored bullets have shown such distinguishing characteristics on bone when compared to the lesion inflicted by the ordinary lead bullet, as shown by dissection and the appearance outlined on an X-ray plate, that they deserve special mention at this time. The use of jacketed bullets is becoming more and more popular with the manufacture of pistols. The question of the kind of weapon, as well as the kind of bullet, whether jacketed or not, can be established by strong presumptive evidence from the presence or absence of lead particles on the X-ray plate. A lead bullet fired from an ordinary revolver at moderate velocity leaves particles of lead in the osseous lesions and their vicinity, in nearly every instance; and the reverse is true if the lesion has been inflicted by an automatic pistol carrying a jacketed bullet. The osseous lesion i ı the case of the latter is, as a rule, remarkably free from metallic particles unless the nose of the bullet has been marred by filing, etc. Military surgeons in the wars of the present distinguish at a glance on an X-ray plate wounds from shrapnel balls which are always made of lead from those inflicted by the mantle projectiles of the reduced-caliber rifle. In the former, in the osseous lesion and the soft tissues beyond the point of impact in the bone one will find deposits of small fragments of lead distributed in a stream-like manner. The bone lesion from the jacketed bullet is usually free from metallic particles unless there has been separation of the jacket from the lead core. Such fragmentation will sometimes take place when the

jacketed bullet makes an irregular impact against the bone or when its jacket has been impaired by ricochet or otherwise. If the plate should show absence of lead particle, the use of a jacketed bullet is indicated and since the latter are only used in pistols of the automatic class and not in revolvers, the kind of weapon also becomes apparent. A study of figures representing X-ray lesions in bone in other chapters will show the differences referred to.

In any case that is likely to go before the courts, the examiners should take careful notes at the time of the first examination, and preserve these for future reference. The exact location of the entrance and exit wounds, if the latter is present, should be noted. The character of the wounds, their size and shape, their condition as to laceration, the character and amount of hemorrhage and evidence as to powder brand and tattooing will be important points to note. When a post-mortem is held, minute notes should be taken of the findings, and filed. The condition of the weapon, its location when found, the presence or absence of smut in the barrel should also be noted.

In the foregoing medico-legal phases of gunshot wounds we have endeavored to consider the majority of the questions that are likely to come up in courts of law. There are doubtless many more that writers on the subject cannot foretell. Thus the dangers from certain body wounds and the complications likely to set in cannot be dealt with at length in this chapter. They can only be grasped by a careful study of the chapters devoted to these subjects. For further particulars on the various kinds of explosives, firearms, projectiles and the characteristic features of gunshot wounds by different weapons the reader is referred to Chapters I and II.

CHAPTER XIV

Field X-ray Apparatus

The importance of radiography in dealing with military surgical cases in war has long been recognized, and many different types of apparatus have been devised for doing radiography under the conditions of active service. Up to the present time, however, no apparatus has been free from some one or more serious defect. The essential features of a field X-ray apparatus are sufficient power for good radiography and at the same time portability, compactness, and durability.

The use of galvanic cells in connection with a coil was one of the first types suggested for field apparatus. It is a laboratory possibility to illuminate a Crooke's tube by a series of galvanic cells, but, owing to the small current produced, the quantity and quality of the radiations are unsatisfactory.

Static machines were designed but were abandoned on account of numerous difficulties attending their operation. They were too cumbersome, too fragile, and extremely unreliable. Hand power applied to a static machine is a poor method of operating the machine, so that an engine must be provided for uniform high speed. If an engine were available, however, it would be better to employ it with a coil-dynamo apparatus which is of greater radiographic efficiency.

During the Boer War, accumulators were frequently used with coils by English medical officers, and appear to have given satisfaction. There are two objections to the use of accumulators that prevent their adoption for field service. Their weight is excessive, but this is not so objectionable as the fact that they require an electrical supply to recharge them. If no means of recharging the apparatus be available, it is worthless in that locality. The recharging of accumulators requires a direct current, but an alternating current can be used after passing it through a rectifier. The absence of this rectifier, however, would preclude recharging. Accumulators may at times be employed for field X-ray work, but the ideal apparatus for this purpose must be self-contained and operable at any time and under all circumstances.

Among the early forms of apparatus were coil-dynamo machines

operated by man or horse-power, a revolving shaft transmitting the power to the dynamo. A tandem bicycle was also used, being constructed so that it could be connected to a dynamo by a chain drive. These methods were never found satisfactory, as sufficient power could not be generated. Later a gasoline engine was employed to furnish the power and was found practical.

The coil-dynamo machine operated by a gasoline engine is one of the best types of field X-ray apparatus and the medical departments of most armies have adopted it. Difficulties that have attended the operation of this apparatus, in most instances, have been with the engine. No gasoline engine has been found that has given perfect satisfaction when operated in connection with a coil apparatus. The difficulties have chiefly been with vibration and in an annoying variation in the speed of the engine when the current is switched on and off the coil. Small, one-cylinder marine engines of $1\frac{1}{2}$ to 3 H.P. acquire a marked vibration when running at full speed and must be anchored securely to a base. This vibration is reduced in a two-cylinder engine which weighs only slightly more, runs much better, and is altogether more satisfactory. The variation in the speed of the engine is due to the peculiar conditions attending the operation of a coil. Ordinarily a gasoline engine runs under a uniform load throughout its operation, but with a coil it is subjected to a sudden change from no load to full load and *vice versa*. When the current from the generator is switched into the coil, the engine drops slowly in speed and the voltmeter will show a corresponding fall. Opening up the throttle to a greater degree will slightly counteract this retardation. Upon throwing off the coil switch which removes the load from the engine, there is a sudden acceleration in its speed, and the throttle should be adjusted accordingly. This action is much less marked in a two-cylinder engine of 4 to 6 H.P. operating a 2-K.W. generator.

The ignition devices on gasoline engines for field X-ray apparatus are important and require some consideration in their selection. A good reliable high-tension magneto should be used. The use of dry-cell batteries to initiate the current necessary for the spark plug is objectionable. They become exhausted in time and must be replaced by new ones. This may occur in the field at times when no cells are procurable.

Recently a 5-H.P. motor-cycle engine was used to operate an interrupterless apparatus constructed for field service. It was run at a speed of about 1200 R.P.M. This is much faster than a marine

engine and makes it possible to connect engine and generator by the same shaft. The engine worked satisfactorily but there was some difficulty in cranking. A spring cranking device has been used but with only small success.

The desired current for a field X-ray machine is about 20 amperes at 110 volts which is furnished by a 2-K.W. generator. A generator of 2-K.W. capacity requiring a speed of 600 to 800 R.P.M. is too heavy for field use and selection must be made from the smaller types that deliver the same current at 1200 to 1800 R.P.M. This speed is in excess of that of the ordinary marine engine and consequently it is necessary to connect engine and generator by a chain drive for multiplication. The high speed of the motor-cycle engine makes it possible to mount the generator and engine on the same shaft, and for this reason, together with its comparative light weight, it is a desirable engine for field apparatus. However, the excessive vibration of an engine which runs at this speed is a serious disadvantage. It must be overcome by means of one of the various forms of shock absorbers, else an outfit will soon shake itself to pieces.

The best coil for general radiography is one of 10–12-inch sparking distance. This size is the one sold by most X-ray apparatus manufacturers. It is not excessive in weight and is best suited to our purpose.

Of the several types of interrupters now on the market, none have given as much satisfaction as the electrolytic. A mechanical interrupter would be an ideal apparatus provided a high speed of interruptions could be maintained without injury to its parts when working with strong currents. A simple mechanical interrupter of the App or vril type is not satisfactory when working with a 20-ampere current at 110 volts pressure, since the contact points become burned out and the apparatus ceases to work. Various mercury turbine interrupters have been tried but they are inferior to the electrolytic. The great objection to the electrolytic interrupter is the necessity of equipping the apparatus with a large amount of sulphuric acid, for there is always the risk that the glass bottles containing this acid will become broken in transportation and cause much damage. To offset this disadvantage it has been suggested that chromic acid be used instead of sulphuric. Chromic acid is crystalline, can be readily handled, and in 1 to 10 aqueous solution works well.

During the past year the Medical Department, U. S. Army, has

carried on a number of experiments with field X-ray outfits. Instead of using the induction coil, all the outfits are of the interrupterless type. They consist of a gasoline engine, 5 to 7 H.P., directly connected to drive a 2 K.W. A.C. generator. From the generator the current passes to a transformer where the voltage is stepped up to about 100,000 volts. On the same shaft as the generator and engine is fixed a mechanical rectifier or commutator so adjusted that its poles convert the two pulsations of the A.C. coming from the transformer into a pulsating direct current which passes to the X-ray tube. The opera-

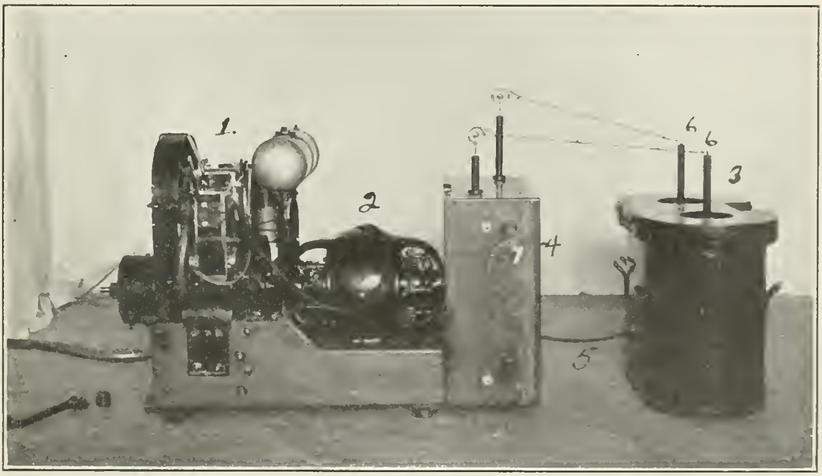


FIG. 157.—Type of field X-ray apparatus with motor-cycle engine. 1, Engine; 2, motor; 3, transformer; 4, box containing revolving rectifying switches; 5, cable containing wires for circuit from motor through primary of transformer and return; 6, secondary terminals of transformer; 7, terminals through which current is carried from rectifying switches to the X-ray tube.

tion of the engine and the control of the current is accomplished by a simple adjustment. Two types of engines have been used, a small two-cylinder, 6-H.P. marine engine, and a 7-H.P. motor-cycle engine. The former operates at a lower speed than the latter, and vibration is therefore not so marked. With each outfit excellent radiographic work has been done. Each outfit is complete in itself, being equipped with all the photographic supplies necessary. The outfits are so constructed that they can be quickly and securely packed for transportation, and the containers are so fashioned and so proportioned that they can be easily handled and packed in the ordinary army four-horse wagon. The specifications from the Surgeon-General's office

limits the weight of the apparatus to 2000 pounds, and the maximum weight of the various units in which it is packed for transportation to 400 pounds. This division of weight into several parts is an important factor in handling the apparatus, as each boxed unit can be readily carried by a squad of four men.

Several outfits have been constructed and are now installed at post hospitals for further observation as to their durability and radio-

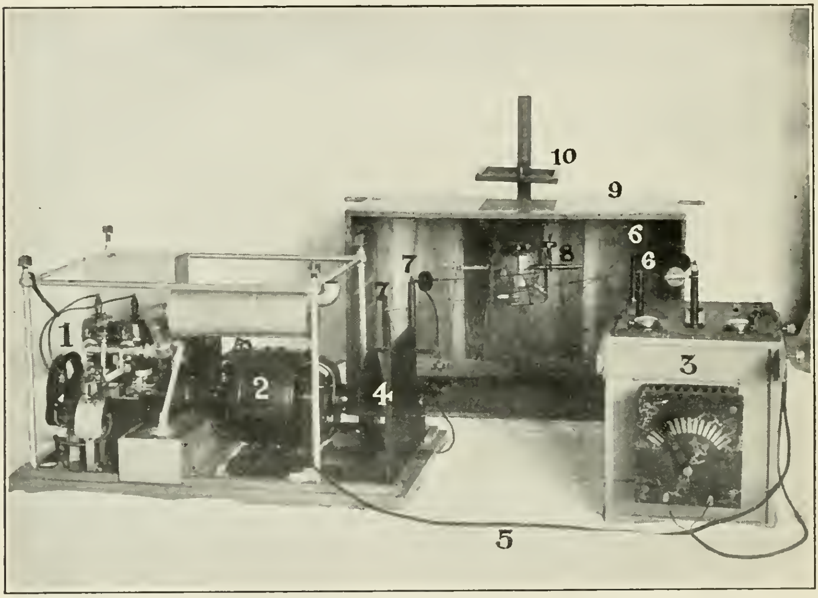


FIG. 158.—Type of field X-ray apparatus with marine engine. 1, Engine; 2, motor; 3, transformer; 4, rectifying switches; 5, cable containing wires for circuit from motor to primary of transformer and return; 6, secondary terminals of transformer; 7, terminals through which current is carried from rectifying switches to X-ray tube; 8, X-ray tube; 9, packing box utilized as table; 10, plate holder.

graphic efficiency. Three of these outfits are shown in Figs. 157, 158, 159. They are in constant use and all defects in construction are being carefully recorded. It is hoped that in a short time sufficient information will have been obtained to enable the department to determine the most satisfactory engine for use with these outfits. Experiments thus far seem to indicate that the motor-cycle engine, while light and very powerful, is too complicated and delicate for use with these machines. It is believed that these experiments will show that a

low-speed marine engine geared or belted to the generator will prove to be the most suitable motive power, these engines being simple in construction, easily operated under almost any conditions, having very few parts, and being much more durable than the complicated light-weight engine. As the X-ray outfits cannot, in the field, serve any purpose at the front—in fact, are not practical or needed further forward than the more or less stationary evacuation hospitals, the increased weight occasioned by using the slow-speed powerful engine is not a serious disadvantage.

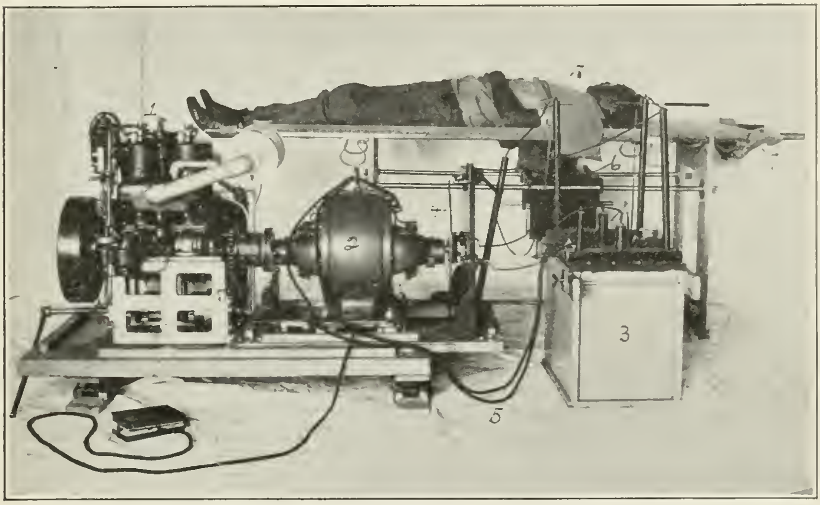


FIG. 159.—Latest type of field X-ray apparatus with marine engine. 1, Engine; 2, motor; 3, transformer; 4, revolving rectifying disc; 5, cables containing wires for circuit from motor through primary of transformer and return; 6, box containing X-ray tube mounted so as to slide on horizontal rods; 7, army stretcher; 8, canvas strip weighted at ends to hold plate in position.

Tubes.—Each apparatus should be equipped with at least four 6-inch or 7-inch tungsten target tubes. To prevent breakage in transportation these tubes must be securely packed. This is quite satisfactorily accomplished by having a special chest made up for the tubes with holders in which each tube can be placed, the chest and holders being thoroughly lined with very thick and soft padding materials. Breakage is certain to be a great factor in any scheme of packing tubes. If space is not a factor, tubes should be packed in excelsior and each tube inclosed in a separate box.

Table.—For use with the portable apparatus described above,

The Roentgen Mfg. Co. of Philadelphia has devised an excellent portable table which can be conveniently folded up for transportation. It is constructed so that an army stretcher forms the couch under which plays a tube supported in a suitable tube holder. The tube holder can be displaced along the length of the couch, while the litter can be moved laterally, the combination of movements making it possible to radiograph any part of a patient without disturbing him. The plate is held by a canvas strip weighted at both ends, so that when it is placed over the plate it holds it securely in position. With this

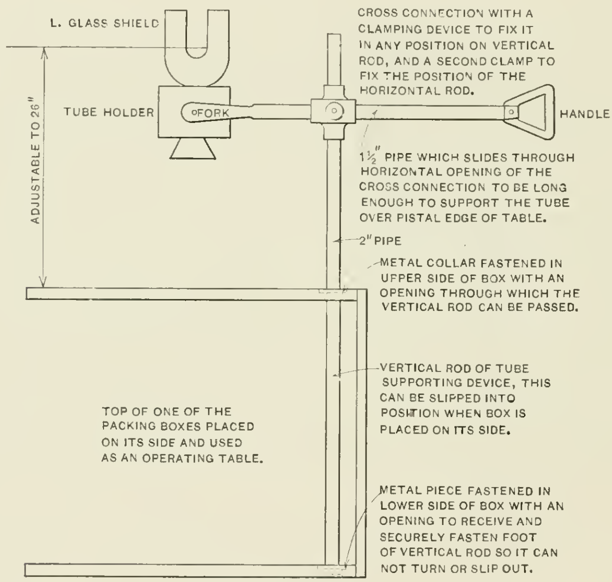


Fig. 160.

form of table excellent radiographic work can be done. However, it is believed more satisfactory radiographs can be made if the tube is supported above the patient. In addition it does not seem necessary to increase the weight of an outfit with a special operating table, when the apparatus must be packed in a number of large boxes one or more of which can be utilized as a table. Means can easily be provided for supporting an adjustable tube holder above one of the boxes. Fig. 160 shows a rough sketch of a table of this kind, one of which has been made up by the Waite & Bartlett Co. of New York City in connec-

tion with a field X-ray apparatus built by this company, and it has proven entirely satisfactory.

Dark Room.—The Surgeon-General's office has had several portable cabinets constructed, all of which have for a time proven satisfactory. But these cabinets are not durable and under the rough usage incident to field service the materials of which they are constructed cannot be depended upon to provide a light-proof compartment. Pending further developments in the line of portable dark room it seems that in the field some of the numerous forms of developing tanks must be used for developing X-ray plates. These tanks give good results and while their product may not be equal to that which can be obtained in a well-equipped dark room, yet the plates produced furnish all the information ordinarily required under field conditions.

The accessories required for a complete field apparatus are a supply of X-ray plates, fluoroscope, lenticular stereoscope, chemicals for development and printing, trays, printing paper and frames, orange and black envelopes for the protection of plates, graduates, tool kit and important spare parts for the engine, and a tank for gasoline.

A field X-ray apparatus in order to be portable must either be mounted on an automobile or wagon bed or divided into several parts which can be boxed. The French Army has constructed an X-ray automobile, which is said to be very satisfactory. Its engine provides power for the operation of the apparatus. The German Army uses a wagon and their apparatus is one of the best for field service. The apparatus used by the United States Army is contained in several boxes which can easily be loaded into an escort wagon. The last method appears to be practical and reliable. Disabling accidents are liable to happen either to an automobile or wagon, especially the former, so that the construction of an X-ray apparatus permanently upon either does not appear to be as good as separate boxing. The last method is certainly best adapted for boat and railroad transportation.

In regard to the proper points at which field X-ray apparatus should be operated when an army is in active service, it is the general opinion that they are not required further forward than the stationary hospitals along the lines of communication. They should not be a part of the equipment of a field hospital. According to the present organization of our medical department, field hospitals are daily evacuated to the stationary hospitals, and all cases that require skiagraphy can safely stand the delay of a day or two incident to their arrival at the hospitals in the rear. The presence of an X-ray apparatus at

a field hospital would tend to foster unnecessary surgical interference and add greatly to the work at that point. The large military hospitals at the base will be equipped with permanent X-ray apparatus, but it is probable that, at the beginning of a campaign, it will there be necessary to use portable outfits while awaiting the installation of other apparatus. In this connection it is to be stated that there is some difficulty attending the initial installation of permanent coils and other X-ray apparatus, owing to variations in local electrical currents. If the character of the electrical supply for a particular place be known, the supply department can provide an apparatus constructed for that current. In supplying an X-ray apparatus for a certain place it is necessary to know the character of the current, whether direct or alternating; the voltage; and, if the current be alternating, its cycle and phase.

The construction of portable field X-ray apparatus has not yet reached perfection but every endeavor is being made by the Surgeon-General's office to secure an apparatus that will warrant its use at army posts during times of peace, so that medical officers will become familiar with the operation of the apparatus and there will be a large supply of field outfits available at once for service during active warfare.

INDEX